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THE IMPACT OF FACSIMILE ON THE DCS.(U)
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DEFENSE COMMUNICATIONS ENGINEERING CENTER

TECHNICAL REPORT NO. 10-79

THE IMPACT OF FACSIMILE ON THE DCS

DECEMBER 1979

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Facsimile is experiencing rapid growth because of decreasing costs, technological improvements, and the increasing costs of the competing traditional communications services. This report identified DoD applicability of facsimile, possible problems to the DCS, key issues to be resolved, and anticipated user needs for the near-term DCS.

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TECHNICAL REPORT NO. 10-79

THE IMPACT OF FACSIMILE ON THE DCS

December 1979

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FOREWORD

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EXECUTIVE SUMMARY

1. OVERVIEW

Facsimile is currently experiencing rapid growth as a more convenient means for handling narrative as well as graphic communications. This growth is primarily due to the ease of use and decreasing costs of facsimile service relative to the more traditional communications services such as teletype and the U.S. Mail. The potential benefits which these developments offer to military communications are being viewed with increasing interest by DoD. However, the specific nature of the impact which facsimile could have on military communications has not yet been fully explored.

The purpose of this report is to identify the potential uses for facsimile in the DoD, bound the problems that this use may pose for the DCS, identify the key issues to be resolved and evaluate the impact that anticipated needs for facsimile service could have on the near-term DCS. Evaluation of the impact of facsimile on the future DCS is currently in progress and is expected to be available for consideration in developing the next DCS Ten Year Plan (FY 84-94).

The discussion in this report is presented from the viewpoint of both the impact of anticipated user needs on the communications network and the impact of current network constraints and design concepts on the needs of the user.

2. THE PROBLEM IN PERSPECTIVE

Traditionally, facsimile has existed as a relatively minor telecommunications service primarily for transmitting time sensitive graphic material such as news photographs and weather maps. Since the mid 1970's, however, this traditional view of facsimile has been rapidly changing, largely due to increasing transmittal of narrative traffic for which facsimile might appear to be less efficient than other available services. This changing emphasis for facsimile application is primarily due to:

- The increasing need for faster and easier means of coordinating and communicating ideas.
- The increasingly favorable cost position of facsimile relative to the more traditional communications services, such as teletype and the mail.

To gain a better insight into user needs for DoD facsimile service, the Naval Ocean Systems Center (NOSC) was funded by DCEC to conduct a survey of current and projected facsimile demand within DoD. The following conclusions resulted from this survey:

- There is a considerable need for an informal action officer-to-action officer hardcopy service for the purpose of staffing command actions preparatory to "official" release.

- In those cases where a facsimile network has been superimposed over an existing teletype network, teletype traffic has been reduced substantially in favor of facsimile, due primarily to greatly improved operational and maintenance efficiencies.

- There is considerable expressed need for a "next-day-of-delivery" type service that is more responsive than the mail but would not require the much shorter delivery times currently specified for AUTODIN messages.

- Many users see the inexpensive analog CONVENIENCE facsimile terminals as a means of bypassing the inconvenience of existing on-base common-user distribution systems.

- At least a 10-fold growth in DoD facsimile demand can be expected before 1990. This increase could be much more if the electronic transfer of high resolution photographs becomes a major DoD requirement.

3. KEY ISSUES INVOLVED

a. TECHNICAL ISSUES

The main impact of facsimile on the DCS will be increased traffic volume, even though the holding time and message length distributions may be significantly different from voice and teletype traffic.

This increased traffic volume will result from a combination of two factors: (1) more information will be transferred electrically because of the increased availability of facsimile, and (2) the transmission of a page of narrative by facsimile will, in general, require more bits than transmission by teletype or optical character reader (OCR). The second factor is dependent upon the quality desired in the received copy, the efficiency with which the copy is reduced to electrical form for transmission, and the degree of compatability between the various terminal equipments.

(1) Quality. Received copy quality is primarily determined by the resolution and contrast (number of gray scale levels for digital transmission) selected for transmission. An increase in resolution and, for digital

applications, contrast, is attended by a disproportionate increase in the number of bits to be transmitted and thus the circuit utilization time required for document transfer. In many applications, the user states his requirement for resolution and contrast without understanding the differences between inadequate resolution/contrast and other transmission or equipment impairments.

(2) Transmission Efficiency. The large number of bits required for a typical digital facsimile transmission can be offset somewhat by implementing various compression techniques that reduce copy redundancy. The best technique for a particular application is dependent upon the type of copy being transmitted and the nature of the environment through which the transmission is being made. Digital transmission is the most efficient means for transmitting alphanumeric and simple graphic information, while transmission of photographs requiring gray scale resolution is generally more efficient by analog means.

(3) Compatibility of Terminals. There is currently full compatibility within the United States and Canada at the six minute analog transmission rates and fast approaching for the two/three minute rate. Compatibility for digital equipments operating at the faster transmission rates appears to be still a long way from reality, although full equipment compatibility is becoming less important as network translation capabilities based on LSI technology become available.

b. NON-TECHNICAL ISSUES

The FAX problem can be examined from the perspectives of both the users of the service and the providers of that service; the main differences being budgetary. In particular:

- The user views FAX as an opportunity to enhance information transfer between writer and reader, by passing the delays inherent in the majority of existing local distribution systems. To reduce on-base distribution time, he prefers location of the FAX terminal near his desk. He tends to select analog rather than digital terminals, at least for lower volume applications, because of the current disparity in cost between these two classes of equipments. And finally, he prefers to achieve terminal interoperability through the network allowing him to choose from a variety of sources the terminal best suited for his needs.

- The network manager, on the other hand, prefers digital equipment because it allows more efficient data transmission through data compression techniques, and facilitates secure operation. He prefers to locate the facsimile terminal in the

local comm center, due to communications economies as well as security considerations, and strongly prefers terminal standardization as the means to achieve terminal interoperability.

The response of the MILDEP's to this differing perspective varies from Navy, which has officially declared facsimile to be "office equipment", under the management control of the user, to Army, which is moving in the direction of centralized management control within the communications activities. Air Force lies somewhere in between. This situation has indirectly led to the following additional issues relating to the provision of an effective common-user FAX service:

(1) Lease Vs Buy. The GAO report [7] strongly encourages centralized procurement of facsimile equipment, rather than individual leases, as a means to reduce costs. However, with the technology changing so rapidly and the potential users of the service faced with considerable uncertainty as to the form that DoD facsimile service will ultimately take, leasing appears currently to be the best solution for many applications.

(2) On-Base Distribution. There are currently several MILDEP sponsored programs to automate the on-base distribution systems. However, these efforts are mostly directed only at automating the base level segment of the existing "official" message network and do not cover the convenience needs which are largely responsible for facsimile's increasing demand.

(3) Current Backbone Pricing Strategy. The current method for funding the DCS switched systems was developed under the concept of centralized management control where the main problem was how best to divide up the pie between the MILDEP's, with the decision as to which solution best meets the users' needs left to the communicator. Under this scheme, AUTODIN appears to be much more expensive and AUTOVON less expensive to the potential FAX user than the actual cost to the DoD would indicate. This situation does not encourage the user, faced with making his own decision, to select the type of communications service that is most cost-effective, nor to use that service efficiently, once obtained.

(4) Current Policy Guidance. The current policy guidance concerning the use of facsimile over the DCS strongly favors digital over analog solutions for all facsimile applications, and attempts, to establish "universal" interoperability between all DoD users, including the tactical community. The major deficiencies in current policy are:

- JCS guidance states that AUTOVON and AUTOSEVOCOM will "handle essential command and control, operations, intelligence, logistics, diplomatic, and administrative traffic..." The dual nature of the DCS in supporting both command and control and administrative traffic is well established. However, the use

of the term essential in JCS guidance as applied to administrative traffic is ambiguous and subject to different interpretations on the part of the user and the communications providers.

- Current policy addresses facsimile as a single entity; however, the impact of facsimile on a particular subsystem of the DCS must be evaluated separately for each of five major application categories.

- Current GAO policy guidance [7] "encourages strongly the use of common-user or shared facsimile equipment, if appropriate." Although this policy is based on sound economic advice, discussions with MilDep communicators indicate that it is being interpreted too stringently in some areas, thereby denying a major benefit of convenience facsimile service in reducing delays experienced in the local distribution networks and with the US Postal Service.

(5) Message Accountability. A common complaint leveled at convenience facsimile is that it will by-pass the normal message releasing authority. This view appears to be widely held at the command level, which may have discouraged the identification of requirements for facsimile as a common-user service. However, effective message accountability procedures could be developed for facsimile, perhaps employing its ability to transmit signatures or fingerprints. This issue must be resolved before the full implications of facsimile's impact on the DCS can be determined.

4. IMPACT OF FACSIMILE ON THE DCS

a. GENERAL

There currently are four different communications approaches open to the potential DoD facsimile user: AUTOVON, AUTODIN, the public dial network, and dedicated point-to-point leased or Government-owned DCS circuits. Which is selected for a particular application depends in part on the user's perception of the relative merits of each - which may not coincide with the views of the communicator. The following four factors appear to guide the users' choice:

- Ease of obtaining service

- User cost

- Service reliability
- Security.

The interrelationships between each facsimile application category and the various subsystems of the DCS are discussed in the report. In general, it is shown that convenience FAX applications will primarily impact AUTOVON, while the special purpose and mailroom applications will primarily impact AUTODIN I and II. The two key problems to be resolved with respect to proper subsystem selection are: 1) whether AUTOVON or AUTODIN I is the most cost effective solution at the lower traffic levels, and 2) whether AUTODIN II will satisfy wideband facsimile needs or become merely a transitional phase into a fully implemented wideband facsimile and imagery service. A basis for answering the first question is discussed in this report. The second question is currently being addressed by DCEC in a follow-on study effort.

In addition, the need for high resolution facsimile in support of the intelligence community has not yet been identified due to security restrictions in the requirement identification process. These requirements could have an overriding implication for the design of future DoD networks supporting facsimile transmission.

b. IMPACT ON AUTOVON

The impact of facsimile on AUTOVON was analyzed through computer simulation models. The viewpoint taken included both the effect of increasing demand on the overall Grade of Service for the existing voice network, and the costs of expanding the network to maintain the current grade of service as facsimile demand increases.

These analyses led to the following conclusions:

- The use of AUTOVON for facsimile service is being discouraged due to the preemptive nature of the network and its heavy traffic load during normal duty hours. However, AUTOVON has a considerable capacity for FAX operation in the after-hours if a store-and-forward capability, utilizing unattended terminal operation or network assets, can be implemented.
- Increasing facsimile demand during normal duty hours will have a significant impact on AUTOVON grade of service if backbone and access area circuit assets are not augmented accordingly.
- Even without a network store and forward capability, AUTOVON can be a cost-effective alternative to both commercial service and AUTODIN for the non busy hour low volume facsimile applications if a low cost store and forward facsimile compression capability, such as provided by FAX-COMP, is made available at the user's location.

c. IMPACT ON AUTODIN I

Three types of constraints limit increased facsimile traffic on the AUTODIN network: switch termination capacity, switch throughput limitations, and the costs of additional interswitch trunks. Applications of these constraints to the AUTODIN network for expected high and low utilization rates are developed in the report. The following conclusions can be made from the preliminary analysis:

- Provision of an automatic interface between the AUTODIN and the local dial or AUTOVON networks would significantly increase the effectiveness of the DCS in meeting convenience facsimile demand and would reduce the impact which facsimile is having on AUTOVON.

- The use of AUTODIN I for facsimile service is being encouraged. However, the ability of AUTODIN I to handle sequential delivery, as required for facsimile transmissions much above 500 line blocks in length, will limit AUTODIN I's effectiveness in meeting any significant increase in non-narrative facsimile traffic demand.

- Due to the large number of bits involved,and the difficulty of applying effective compression techniques, the transmission of high resolution photography (information densities requiring 400 LPI resolution and 16 levels of contrast or greater) cannot be adequately supported by AUTODIN I.

d. IMPACT ON DCS II

The impact which wideband facsimile applications and, in particular, electronic mail, could have on DCS II is currently being investigated by DCEC The following appear to be the main areas for concern:

- The efficiency of packet versus circuit switching techniques for large volume (megabit) facsimile transmissions.

- The economic necessity for a large buffer/storage device, beyond AUTODIN design limits, to be located between the local base area and the communications network to facilitate network load equalization and multiple delivery.

- The implication of DCS II network design on the terminal options available to convenience facsimile users.

- The expected cost of DCS II service for convenience facsimile users.

5. CONCLUSIONS

Pending identification of the facsimile needs of the intelligencce community and the implementation of DCS II and its modification for full electronic mail service, current technology and networking concepts are available

from at least one manufacturer (Compression Labs) which could combine the best attributes of both AUTOVON and AUTODIN in providing an effective interim DoD facsimile service. With this in mind, the report concludes with the following recommendations:

- That current policy directives and DCS pricing strategies be revised to reflect facsimile as a fully mature telecommunications service.
- That a full study effort, in coordination with the MilDeps, be initiated to evaluate the desirability of electronic mail for DoD application.
- That the intelligence community be asked to provide a commprehensive assessment of their needs for future facsimile service.
- That a pilot test program be initiated utilizing Compression Labs equipment (or equivalent) to demonstrate the feasibility of an interim AUTOVON/AUTODIN I combined facsimile service.
- That pending implementation of a fully responsive DCS facsimile service, the MilDep's be encouraged to procure store and forward facsimile compression equipment, such as FAX-COMP, for use at the local level with their analog facsimile equipment.

I. INTRODUCTION

1. PURPOSE

Facsimile (FAX) is currently experiencing rapid growth as a convenient means for handling narrative as well as graphic communications. While facsimile is not new, recent developments have greatly reduced the cost of facsimile terminal design and manufacture. These reduced terminal costs, coupled with the increasing cost to transfer information by many of the more traditional means (such as teletype and the Postal Service), have added considerable impetus to facsimile's use. The potential benefits which these developments offer to military communications are being viewed with increasing interest by DoD. However, to date, the specific nature of the impact which facsimile could have on military communications has not been fully explored.

The purpose of this Technical Report is to bound the problems that facsimile may pose for the DoD, identify the key issues to be resolved, and evaluate the potential impact that anticipated needs for facsimile service could have on the current DCS. The impact that facsimile could have on the future DCS is still under investigation and will be addressed in a follow-on effort covering the major issues unresolved by this report.

2. BACKGROUND

Several current DCA and MILDEP programs address specific aspects of providing facsimile service to the DoD user community. Noteworthy of these are the TRI-TAC Tactical Digital Facsimile (TDF) development program, the WASH-FAX III Network, and the DACOM 412 interface with AUTODIN. However, these efforts are primarily directed at restricted user communities or at the subsystem rather than the system level and do not reflect facsimile as a composite telecommunications service.

The need to address facsimile on a systemwide basis was recognized by Headquarters DCA in reference [1], which tasked DCEC to conduct an in-depth analysis of the broad spectrum of facsimile-type telecommunication requirements and their potential for impacting the DCS. The following major areas of concern were identified by DCEC as requiring consideration in support of this task:

- Identification of the near-term requirements for facsimile and determination of their impact on the present DCS.
- Investigation of the trends which can be expected in the application and growth of facsimile in the DoD community for the foreseeable future.

- Examination of the impact which these trends may have on the future DCS and identify areas where potential design shortfalls may arise.

- Evaluation of these shortfalls in terms of current design concepts and policy guidance for the purpose of establishing a unified approach to DoD facsimile telecommunications planning.

- Development of the mid-term and long-range architecture(s) necessary to fully implement this approach in support of projected DoD requirements for facsimile service.

- Review of the architectures selected with respect to the current DCS to determine appropriate transition strategies.

3. METHOD OF APPROACH

In approaching the DCA task, it was found expedient to divide the work effort into three phases: 1) a preliminary effort, by DCEC, to bound the areas of interest, identify key issues involved, and evaluate the potential for impacting the present DCS; 2) a supporting effort, by the Naval Ocean System Center (NOSC) for DCEC, to more clearly characterize the needs of the MILDEP's and CINC's for facsimile service; and 3) a follow-on effort, by DCEC in coordination with DCA and the MILDEP's, to evaluate the impact of facsimile demand on the future DCS and to develop solutions for implementing a responsive DoD facsimile service in support of this demand.

This report presents the results of the first two task phases with regard to the current DCS, together with a general tutorial of the subject area for those not familiar with facsimile as a common user telecommunications service. The follow-on effort is currently in progress and is expected to be completed by the end of FY 80.

Throughout this report, discussion is conducted from two vantage points: First, from the viewpoint of the user with a need to transfer information in the most cost-effective manner, irrespective of current communications constraints; and, second, from the viewpoint of the communications network designer faced with the technical and economic realities of providing a telecommunication service to meet user needs.

II. FACSIMILE AS A TELECOMMUNICATIONS SERVICE

1. DEFINITIONS AND TERMINOLOGY

a. Definitions

(1) FACSIMILE - Any telecommunications application, wideband or narrowband, by which narrative, graphic, or pictorial information is directly converted from page or other documentary form into an electrical analog for transmission to a distant location; and a reasonably faithful copy or "facsimile" of the original is permanently recorded at the receiving end. In this respect, facsimile can be thought of as indirectly perceived imagery.

(2) RELATED SERVICES - The closely associated services of Directly Perceived Imagery (DPI) and Optical Character Recognition (OCR) are differentiated from facsimile by either the nature of the copy offered for transmission, or the electrical form in which the copy is initially transposed. In particular:

- Directly Perceived Imagery (DPI) is taken to apply to those telecommunications services by which an image of a physical object, or set of objects, is directly converted into electrical form for transmission without first being permanently recorded as a photograph, strip chart, or some other hard copy form. Examples of DPI are TV, slow-scan video, and certain sensor systems wherein the image is transmitted as perceived without first being processed and coded into digital form.

- Optical Character Recognition (OCR) applies to those telecommunication applications wherein the scanned image of the document is matched with a predetermined set of characters or symbols, and a coded representation rather than a facsimile, is transmitted to a distant location for printout. To the extent that both facsimile and OCR begin with similar scanning processes, they are complementary - a fact which is currently being recognized in the development of hybrid FAX-OCR terminal devices.

b. Facsimile Application Categories. Facsimile can be divided into two major subdivisions:

- CONVENIENCE FACSIMILE - Wherein the service is offered primarily for the convenience of a general class of users and the terminal is operated by the user, rather than by specifically assigned personnel.

- OPERATIONAL FACSIMILE - Wherein the service is offered primarily in support of a specific operational function, such as weather dissemination, mail distribution, or command and control, and the terminal is operated by specifically assigned personnel.

Facsimile's traditional role has been in the operational area. However, with recent decreases in the cost of facsimile terminals and increased ease of operation, the convenience aspect of facsimile is becoming more and more prevalent. Unfortunately, this situation has led to a proliferation of terms which are confusing and may be interpreted differently by people with differing interests. To help resolve this situation, the spectrum of facsimile applications is divided into five application categories. These categories are identified in Table I, together with the typical transmission speeds associated with each, and discussed in the following paragraphs in terms of the fundamental attributes most descriptive of each.

TABLE I. FACSIMILE APPLICATION CATEGORIES AND ASSOCIATED CLASSES OF EQUIPMENT

APPLICATION CATEGORY	LOW SPEED* 4-6 MIN GROUP I	MEDIUM SPEED* 2-3 MIN GROUP II	HIGH SPEED* SUB-MIN $\leq$ 9.6 kbps GROUP III	HIGH SPEED* SUB-MIN $\geq$ 9.6 kbp GROUP ?
CONVENIENCE FAX				
DESK TOP	X	X		
CENTRALIZED		X	X	
OPERATIONAL FAX				
MAILROOM		X	X	X
WIDEBAND				X
SPECIAL PURPOSE	X	X	X	X

*Nominal Time to Transmit a Single Page

(1) Desk Top Convenience FAX - A decentralized convenience facsimile application wherein the facsimile terminal is located either on the desk of the user or in his immediate vicinity. Facsimile equipment in this category is generally considered to be office equipment and is characterized as being low cost, operating in the analog mode, portable, and connected to the communications network via an acoustic coupler and a dial-up phone line.

(2) Centralized Convenience FAX - An application wherein the facsimile terminal is provided for the convenience of the user, but at a central location serving a larger group of users. Terminal equipment is generally more expensive than for desk top FAX and may have added features such as automatic loading, automatic transmission, and loss of line indication, which simplify facsimile operation. Equipment in this category still

operates primarily in the analog rather than the digital mode due to the current lower cost of analog equipment. The digital mode may be used, however, where other considerations such as security and volume, are overriding issues. Connection to the communications network for either mode of operation may be by an acoustic coupler or by a special interface device supplied by the communications network.

(3) Mailroom FAX - A centralized operational facsimile application, operated by either admin or communications personnel, wherein the service provided the user is "over-the-counter". Operational applications other than mail distribution are also included in this category, provided that they are centralized and require specially assigned personnel other than the normal user to operate the terminal. Terminal equipment serving this category may be either analog or digital and, depending upon the usage expected, may vary widely in cost and operational features. Connection to the communications network may be via a dial-up telephone line or an equivalent data grade channel operating at data rates currently up to 9.6 kb/s.

(4) Wideband FAX - A facsimile application in which the bandwidths required for operational reasons are greater than those available from a normal dial-up telephone line or an equivalent data channel. This application is further divided into the two subcategories of Electronic Mail Systems (EMS) and High Resolution Photography (HRP), depending upon whether the bandwidth forcing function is volume (EMS) or resolution (HRP). Terminal equipment associated with this application category is generally expensive and connectivity to the communications network is via special wideband channels.

(5) Special Purpose FAX - A category which incorporates all applications requiring specialized facsimile terminal design. This type of application primarily comprises graphic material such as weather data, news photos, fingerprints, and checks, which do not efficiently fit into the normal page sizes of general-purpose terminal equipments. Applications requiring specialized equipment specifically to support wideband applications are addressed under wideband FAX, except for the magazine and newspaper publishing business whose statistics have traditionally been included under the special purpose category.

The five application categories are summarized in Figure 1 in terms of the primary requirement attributes of resolution and volume. Typical operational costs associated with the different classes of equipment used in these categories are given in Figure 2. The calculations and associated assumptions relating to Figure 2 are given in Appendix E.

2. FACSIMILE IN PERSPECTIVE

a. Historical Overview. Although facsimile is considered to be an emerging telecommunications service, it should be noted that facsimile is the world's second oldest electronic communications device, having been invented in 1842 by Scottish clockmaker Alexander Bain. Bain's concept was quickly developed by English inventor Frederick Blakewell into an efficient facsimile

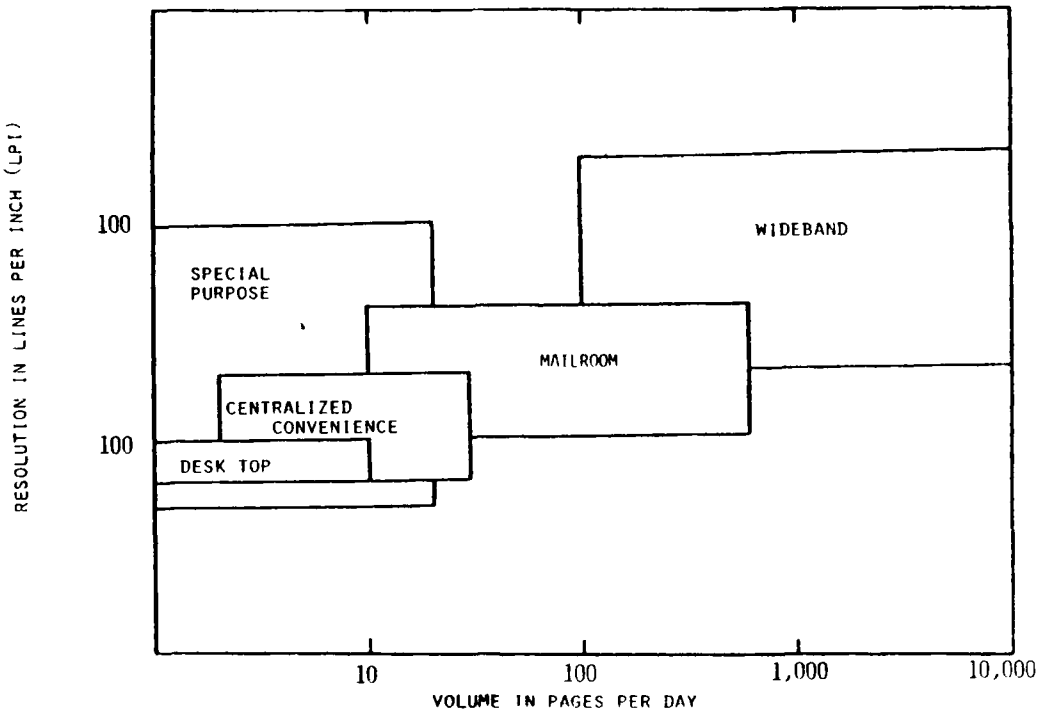


Figure 1. Typical Boundary Values for Facsimile Application Categories in Terms of Volume and Resolution Requirements

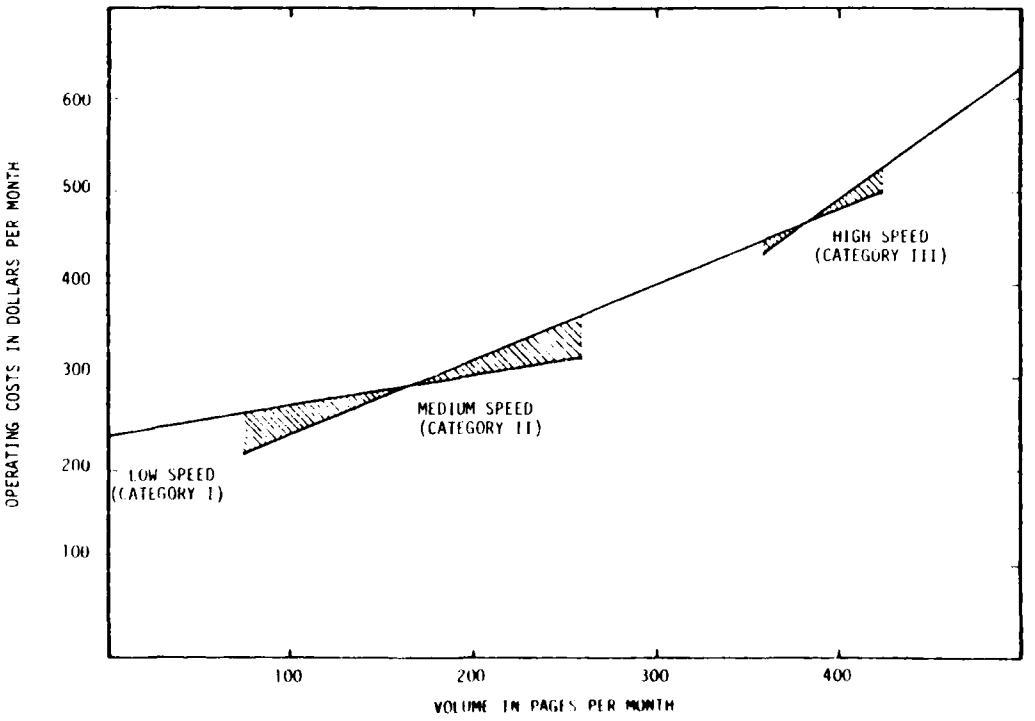


Figure 2. Typical Operating Costs for the Different Classes of Facsimile

unit consisting of a rotating drum around which a piece of paper was wrapped. Developed in 1850, this principle remains one of the primary methods of building low cost facsimile devices today.

The early uses of facsimile were primarily to transmit time sensitive graphic material such as news photographs and weather data. It was not until the 1950's that facsimile began to move beyond these confines into new application areas which had traditionally been the domain of other electronic services or the mail. The most significant of these was the use of some 20,000 facsimile terminals throughout the U.S. by Western Union to expedite the local delivery of telegrams.

Magnavox, in the mid-1960's, introduced relatively low-cost equipment that could be used cost effectively on a "convenience" basis, even in low-volume applications. The market reception for most of these new products was disappointing, and, by 1970, only a few thousand dial-up units were in place, although the intra-company market continued to show a modest gain.

Increasing concern over postal delays and delivery reliability in the early 1970's, together with a steady drop in long-distance telephone charges and increases in personnel costs associated with the more traditional communications services, caused a major change in the outlook for facsimile service. During this period, Xerox introduced newer and more desirable dial-up equipment and mounted a major marketing effort geared towards the concept that facsimile could represent another growth market akin to that of the plain-paper copier. The Xerox marketing push and the growing user demand for facsimile caused the market to undergo a very rapid expansion in the 1970-78 timeframe, from less than 10,000 dial-up units in 1970 to more than 180,000 by the end of 1978.

This trend was momentarily reversed by the 1974-75 recession, but resumed its climb by late 1976. Although the recession did not significantly alter the growth trend, it did set the stage for a major change in market leadership.

During the recession, Qwip Interprises, a subsidiary of EXXON Corporation, introduced a 4/6 minute terminal that leased for $29 per month - almost 2-1/2 times cheaper than the least expensive Xerox device. At the same time, RAPIFAX, the American subsidiary of the Japanese manufacturing company RICOH, marketed a sub-minute digital terminal in competition with the Xerox TC-200, which had been the market leader up until that time. As a result of these marketing efforts, RAPIFAX and QWIP emerged from the recession as the market leaders at both the high and low speed ends of the market, effectively squeezing Xerox into the middle.

To counter the introduction of QWIP and RAPIFAX equipment, a third market segment, centered around the 2/3 minute operating speeds, began to emerge in 1977. In this segment, Graphic Sciences with its family of

interoperable terminals and large installed equipment base has emerged as the leader, again unseating Xerox from its former leadership role.

b. Current Situation. The current growth in facsimile is primarily in the business portion of the market, which has polarized into two separate and diverging segments. One segment seeks very low-cost equipment for occasional "convenience" transmissions, while another segment seeks high-speed, sophisticated equipment to implement high volume "mail" systems.

In the convenience market, decreasing terminal costs have made facsimile less expensive than teletype or TELEX/TWIX services. With the introduction of the QUIP Model 1200, facsimile has been placed within reach of anyone with a need to rapidly transmit even a few pages of graphic or narrative material per week.

In the higher volume message systems, facsimile is fast approaching a favorable competitive position with the Postal Service. Here, the current high cost of facsimile is due only to the need for special, more costly paper, a problem which is expected to be resolved in the next 3 to 4 years with the introduction of improved and lower cost ink-jet printing techniques. Facsimile's application as a high-volume message system device is being further enhanced by the rapid introduction of faster digital terminal equipments with more efficient data compression capabilities.

Growth in both market areas is also benefiting from the establishment of standards which allow interoperability between terminal equipments of different manufacture. Equipment interoperability has already been achieved between most analog machines operating at the 4 to 6 minute speeds and is fast approaching realization for the 2 to 3 minute machines as well. In the area of digital facsimile, however, the failure to decide on a standard compression algorithm is still generally considered a major stumbling block to the rapid growth of facsimile in the high-speed message system market. This problem may not be as serious as once thought as indicated by the results of a study effort, performed for DCEC by NOSC, which establishes the feasibility of providing translation between dissimilar compression algorithms as a feature of the communications network.

Value added facsimile networks are beginning to appear which ultimately will move facsimile from the current hodge-podge of small individual networks, operating generally between closed groups using the same manufacturer's equipment, to a fully international common-user network embracing a wide variety of users and equipment types. Store and forward operation and protocol translation are already being offered by a company called WILTEK, an early pioneer in the development of facsimile networks. These services, and others, are expected to be integral features of ITT's FAX-PAK network, scheduled for operation early in 1980, and Graphic Scanning's (FAX GRAM and DIAL-A-CHECK) new automated facsimile network scheduled for operation shortly thereafter.

WILTEK and others are using a family of equipments produced by Compression Labs, Inc. of Cupertino, California, to provide the networking features of their value added networks. This family of equipments provide analog to digital facsimile conversion, automatic dialing, conversion between different data compression schemes, store-and-forward operation and other networking features which appear to be the first of their kind on the market. A brief representation of these equipments is given in Figure 3.

On the international scene, facsimile is also growing rapidly in Europe and Japan. The Russians have had a public facsimile network in operation between their major post offices since the mid-1950's. The French are currently planning to install more than 1 million digital facsimile machines for general public service over the next ten years [2]. The Japanese, due mainly to a writing system which does not lend itself to coded data transmission, are leading in the field of sub-minute FAX and in the development of sophisticated data compression techniques. In particular, RAPICON (created by a merger of DACOM and RAPIFAX both owned by the Japanese firm RICOH) not only leads all U.S. manufacturers in the placement of sub-minute facsimile terminals in the U.S., but also has the lead in the field of networking via their software connection with IBM mainframe computers. This will enable RAPICON terminals to be linked into major computer networks, such as the ARPANET, and used over AUTODIN.

c. Future Trends. The growth in facsimile, although currently substantial, is just beginning. The market is expected to continue its strong upward growth during the next few years, but with a steadily increasing shift away from 4/6 minute operation and towards 2/3 minute operating speeds.

Wideband facsimile is expected to emerge by 1983, much earlier than previously expected, due to the advent of the SBS and XTEN (Xerox) wideband networks. The emergence of wideband facsimile will undoubtedly have a major impact on sub-minute FAX which utilizes voice or equivalent data grade channels. In effect, sub-minute FAX may be squeezed out of the market by the less expensive 2/3 minute equipments at the lower end of the volume scale and by wideband operation at the higher end.

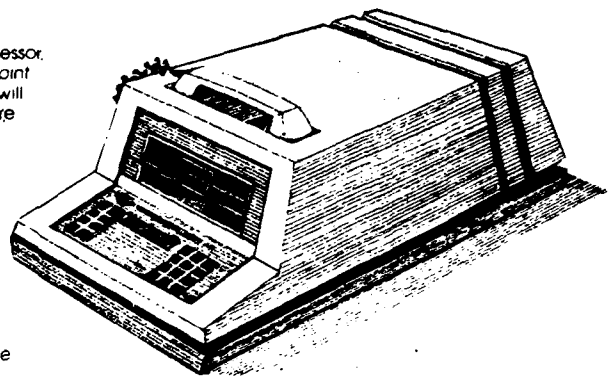
Networking will continue to mature as additional features are added which will allow operation between digital equipments using different compression algorithms, between digital and analog facsimile terminals, and between equipments operating at a wide range of operating speeds.

Looking further into the future, beyond the next few years, the following developments affecting facsimile are expected to take place [3], [4], [5] and [6]:

- Personnel costs, which constitute the bulk of the annual life cycle costs for administrative type services, will be the major driving force for the growth of facsimile and its decentralization to the

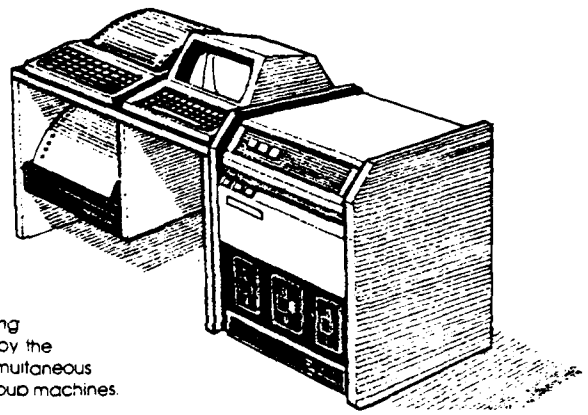
FAX-COMP

The FAX-COMP is a store and forward facsimile compressor, intended to automate the transmission and reception of point to point or point to HUB or POOLER facsimile traffic. The unit will record CCITT Group I, Group II or Group III traffic and store between 5 to 10 pages (larger storage options available) of compressed data on its mini floppy diskette. Features of the unit include off-line storage of multiple pages of material allowing transmission at off-peak hours to multiple locations without page rescanning. Automatic dialing and answering relieves operators for other more pressing tasks. Interfacing of Group I, II or III traffic allows translation among any commonly available facsimile equipments. The automatic answer feature allows unattended answering to be done across different time zones without operator intervention. The autodial feature allows initiation of a delayed sequence of calls at a time when telephone rates are lower.



FAX-POOLER

The POOLER is a store and forward facsimile message switch. The unit allows up to five simultaneous inputs from any of the CCITT Group I, Group II or Group III type facsimile machines. The self-contained floppy disk memory units will hold up to 160 pages of compressed facsimile data. Additional document storage is available in increments of 80 pages. The POOLER can operate in an unattended mode with an autodial feature that will allow delayed off peak time batched facsimile transmissions to minimize telephone line costs. The POOLER can receive and automatically route incoming calls to which touch tone routing data has been keyed by the originator. Up to five incoming telephone lines can route simultaneous calls into the POOLER, originating from any of the CCITT Group machines.



THE FAX-HUB

The FAX-HUB is a high volume translating facsimile message store and forward system that connects directly to standard computer based switchboards. The HUB can translate among CCITT Groups I, II, and III standard machines and can store for subsequent forwarding in excess of 2,000 pages of facsimile information. Storage options are available in 1,000 and 2,000 page increments. The basic HUB system consists of four facsimile ports with the ability to interface Group I, II and or Rapicom or Quick Fax type data. The included control computer can handle up to 28 separate facsimile input/output ports. The FAX-HUB control computer provides control signals for recording both source and destination information about the calls being handled and for logging on an archival 9-track tape unit, allowing subsequent processing off-line for accounting purposes. The FAX-HUB system will provide auto dialing information to the host switchboard for automatically routing out-going calls. The input to the HUB appears as a standard telephone line extension to the host switchboard. A wide range of transmission speeds are available for both digital facsimile input/output and internetwork communications.

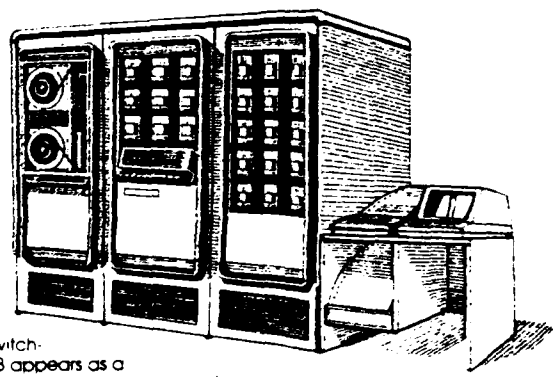


Figure 3. Compression Labs, Inc. - Family of Facsimile Networking Equipments.

source of data entry. This trend will be further enhanced by the increasing need to shorten writer-to-reader time spans.

- With increasing deterioration of mail service as volume grows, and increasing transportation and handling costs, electronic mail systems will likely become much more attractive. This will place a substantial demand on future telecommunications systems.

- The increased used of microfilm for the storage of documents and graphic material will result in a parallel trend in the development of facsimile systems to make technical reference materials of all sorts instantly available by remote automatic retrieval from microfilm libraries.

- The technology necessary for color transmission is currently being demonstrated in the laboratory and should be available for application before the mid-1980s.

- Work patterns will change as screen-to-screen communications proves to be an attractive alternative to business travel. This application will be greatly enhanced by the addition of facsimile peripherals for the transmission of permanent copies of notes, sketches, or other "briefing" type material.

- New optical processors will greatly enhance pattern recognition, associative processing, and other techniques in which a very large number of different data elements must be correlated. Thus, optical character readers will make a reappearance in the form of hybrid FAX/OCR terminal devices, with the operational mode automatically selected on a "line-by-line" or "block-by-block" basis.

- The cost difference between analog and the more efficient digital terminals, currently quite large, is expected to narrow with the application of the gallium arsenide laser diode.

- Further advances in the application of LSI and VLSI technology will provide the potential for full interoperability between differing terminal equipments as a standard feature of the communications network, thus reducing dependence on the establishment of industry standards for achieving equipment interoperability. This capability will continue to be developed during the 1980's and early 1990's until interoperability between even basically different services, such as voice and hardcopy, will become available as a normal network service.

- With the availability of larger transmission bandwidths resulting from optical fiber communications, facsimile will be coupled directly to the office copier and operated at comparable speeds. This merger will be extended even further to provide a "universal" output device

serving the needs of the computer, word processing, and other data and hardcopy services as well.

- The growth of hybrid FAX/OCR terminals will be heavily impacted by the availability of inexpensive Communicating Word Processing (CWP) units in the mid-to-late-1980's.

3. FACSIMILE IN THE DoD

Within the DoD, the traditional application of facsimile has been mainly in the area of the weather services which, ironically, are apparently now moving away from facsimile in favor of a totally computer-driven data system scheduled for implementation by the mid-1980's.

Nevertheless, various organizational elements within DoD are taking advantage of the benefits that facsimile can offer as evidenced by the rapid growth in equipment either purchased or leased by the MILDEP's. This is particularly true of the less expensive facsimile equipment, such as the QWIP 1200, which is considered by most users to be office equipment rather than communications equipment.

In addition to the individual terminal placements, several large facsimile networks - such as the wideband WASH-FAX network, the Air Force's F-15 Logistics network, and the Army's DARCOM FAX analog network - are being implemented at an increasing pace. In addition, a worldwide common user digital network is being programmed for implementation over the next few years. The F-15 network has grown from three terminals processing less than 300 messages a month in 1973 to nine terminals processing 10,000 to 15,000 pages a month in 1979. This growth appears to be typical of what is happening in other DoD facsimile networks as well.

Additionally, the following developmental efforts, now in progress within DoD, will further enhance facsimile's utility in a military environment:

- The development by Navy (NOSC) of the Tactical Digital Facsimile (TDF) terminal for TRI-TAC. This terminal will replace the outmoded and less efficient analog equipments such as the AN/GXC-7A.

- The development by Army of an AUTODIN I digital facsimile interface for the DCS. This capability is currently being tested at five locations in Europe and CONUS and is expected to be implemented as a standard DCS service in the near future.

- A test and evaluation effort by Navy (NOSC), at the request of DCEC, which has: 1) established the feasibility of providing a capability within the DCS for translating dissimilar data compression algorithms, and 2) tested the capability of the FAX-COMP, manufactured by Compression Labs, Inc., to convert from analog to digitally compressed

facsimile for interface with AUTODIN. It is anticipated that the results of these efforts will be used by DCA as a basis for initiating a series of pilot test programs within the DCS to demonstrate system application of these features.

- The DCA standards program, which is developing facsimile equipment standards primarily for digital facsimile equipment. This effort has been instrumental in shaping the direction in which both the industrial and tactical digital facsimile standards programs are heading.

III. THE DEMAND FOR FACSIMILE SERVICE

1. THE GENERAL NATURE OF FACSIMILE DEMAND

a. Major Market Areas. Notwithstanding facsimile's advantages, it has been "in the shadow of" the telegraph and the telephone for most of its existence. The reason has to do with the time dependence of the electronic transfer of information and the fact that the basic facsimile machine is really nothing more than a device that scans a page, recreating the detected images. What takes a teletype seconds to send may take a low speed facsimile machine 6 minutes, with the corresponding cost for a 6 minute telephone call.

The situation concerning facsimile is now changing rapidly. To fully understand this change, facsimile must first be divided into three separate market areas, each having a somewhat different demand function. These areas, as previously defined in Section II, are SPECIAL PURPOSE FAX; MAILROOM FAX, including wideband applications at the high volume end of the scale; and CONVENIENCE FAX, including both desk top and centralized applications. The following discussion highlights the differences between these market areas:

- SPECIAL PURPOSE FAX mainly covers those applications which have traditionally been facsimile's domain because facsimile does a job that no other media can effectively do. For this category, costs are secondary, since no other communications medium can be nearly as responsive to the time requirement. Although new applications continue to appear, with one of the latest being a high speed system of signature verification introduced by ALDEN, this market area is considered to be relatively mature and is expected to grow at a fairly predictable rate, at least over the time frame addressed by this report.

- MAILROOM FAX covers the spectrum of applications between convenience FAX and special purpose FAX. Within this category costs become more important in the trade-off with time sensitivity, and alphanumeric as well as graphic material is included as candidate copy. This market area is expected to move more and more towards facsimile transmission as the cost of the mail continues to increase and those of facsimile equipment and long distance communications continue to decrease. Additional benefits to be derived from a responsive FAX service in this general application area include reduced writer-to-reader delay and the reduced requirement for specially trained operator and maintenance personnel. This market area is considered to be highly volatile, with the question being more when than whether the market area will convert to FAX operation. However, some of the gains may eventually be lost to newer services, such as computer generated graphics and communicating word processing, as these services reach full maturity in the

mid-to-late 1980's.

- CONVENIENCE FAX covers the lower end of the time/cost sensitivity curve for current applications. In addition, it embraces a potentially larger area where the main constraint is whether electronic communications has become inexpensive enough to attract certain "nice-to-have" needs either currently unfulfilled or met less effectively by other means. In this area cost sensitivity becomes most critical, thus raising the question of facsimile's future role.

Figure 4 depicts the relative percentages of the currently installed terminal inventory attributable to each of the three main market areas. The share attributable to Special Purpose applications, facsimile's traditional niche, dropped from 41% of the market in 1970 to less than 8% by the end of 1978. This is indicative of the trend for facsimile into the business market.

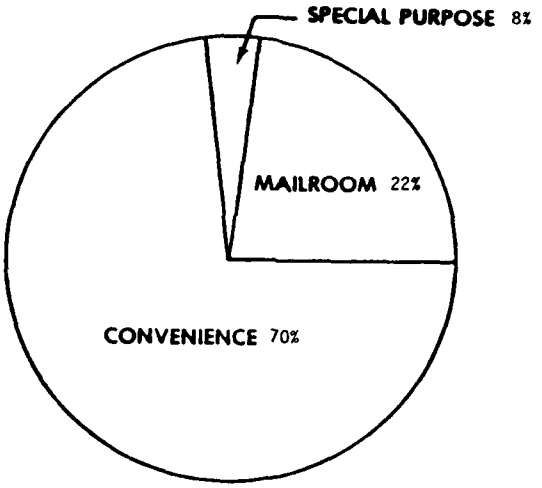


Figure 4. Major Divisions of the Facsimile Terminal Market - 1978

b. Facsimile's Cost Structure. Since facsimile demand is extremely sensitive to costs relative to other communications alternatives, at least for convenience and the lower end of the mailroom categories, a good insight into the cost structure of the facsimile market is necessary in order to evaluate its future potential. The fact that many facsimile users have not

done so is evidenced by the findings of the GAO [7] to be discussed in Part V.

This subsection is directed at the facsimile market as a whole without special consideration for DoD, for it is the total market that will shape the nature and scope of the future industry and thus, the options and strategies available to DoD for facsimile applications. The subject is approached from the DoD point-of-view in the next subsection.

The following are the major points to consider:

- For the average facsimile transmission, less than one-third of the costs are associated with the facsimile terminal, the other two-thirds being transmission costs. This implies that the telephone company is a silent partner and major benefactor in the facsimile industry. The transmission-to-terminal cost ratio increases even more for higher terminal utilization rates. For those cases where transmission costs are perceived as being free by the user, such as may be the case with AUTOVON, total facsimile service costs may appear to be even more attractive.

- The second point to consider concerns when in the typical equipment life cycle the terminal equipment manufacturer may expect to begin showing a profit. A cash flow diagram for a typical facsimile product life cycle, presented by Mr. George Stamps at a IGC Conference on facsimile [6], is given in Figure 5. It can be seen from this figure that for the first 5 years, cash outflow exceeds cash inflow, and only after 7 years, does this particular manufacturer begin to show a profit. The implication of this figure is that the facsimile industry, like "Detroit", is going to introduce new technology into the marketplace at a pace designed to insure maximum continuous profit potential. This situation carries an obvious lesson for the requirements forecaster who has a tendency to overreact to technological forecasts.

- The third point concerns the extreme sensitivity of facsimile market profitability to equipment cancellation rates for leased equipment. In the example cited in Figure 5, a cancellation rate of 40.37 percent (instead of 18.3 percent utilized in developing the figure) would have wiped out before-tax profits entirely. On the other hand, a reduction in the cancellation rate from 18.3% to 7.3% would have increased before-tax profits by 50 percent [6]. This indicates that the vendor, at least in the current phase of market development, must be willing to spend more time and effort in the development of equipment reliability and customer satisfaction in order to reduce cancellation rates and thus show a profit.

- The final point recognizes that an increasingly profitable strategy for manufacturers with older lines of equipment, such as Xerox, is to sell, rather than lease and take the chance that their equipment will

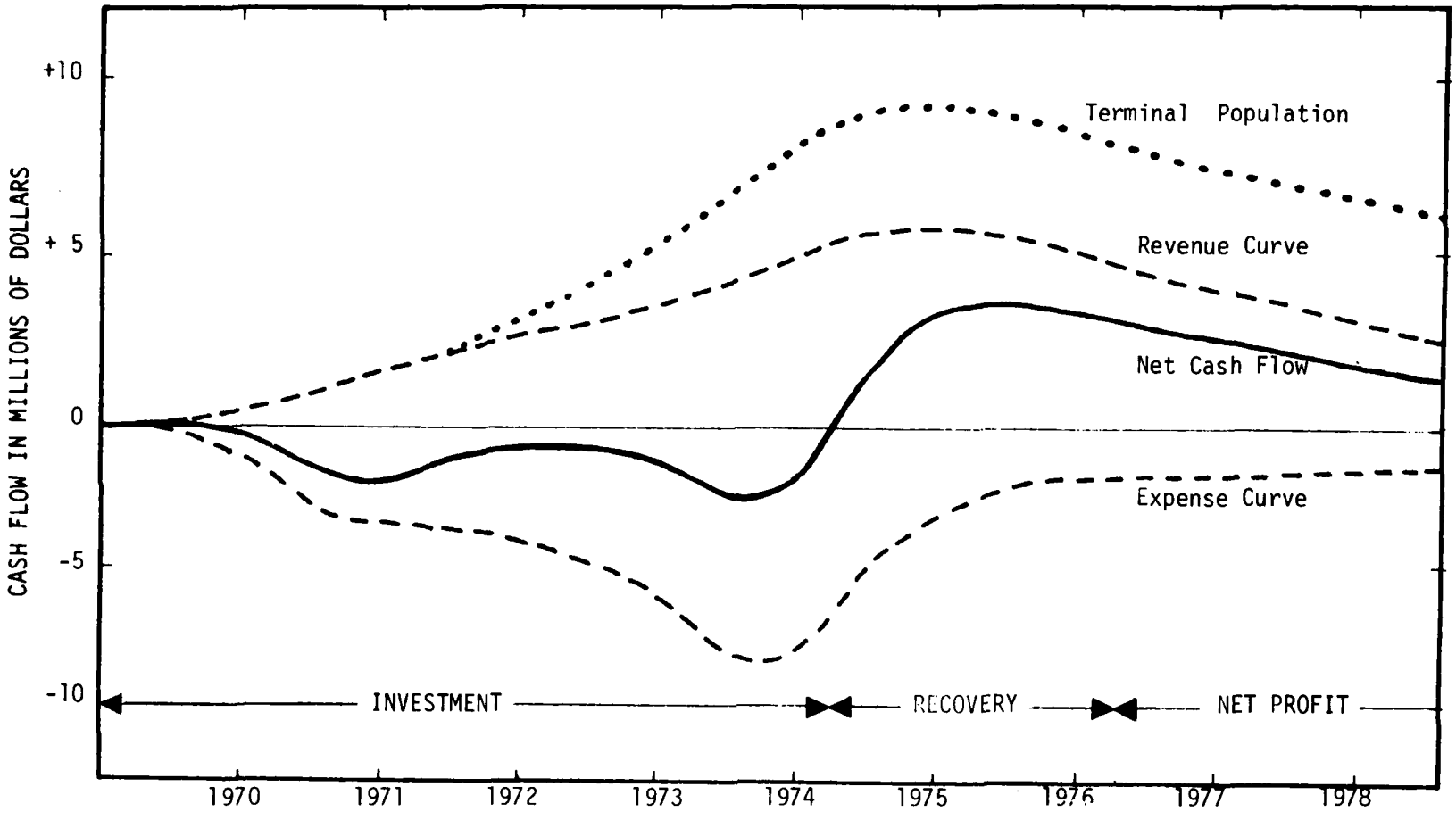


Figure 5. A Typical Facsimile Product Life Cycle

be returned when newer less expensive terminals become available. Since the current facsimile market is largely a rental market with less than 25 percent of the equipment purchased by the user, it is clear that the equipment available for purchase is heavily biased towards the older more obsolete terminal models.

The above considerations, coupled with the currently available 30 day to 90 day leasing arrangements being offered to encourage market expansion and the dynamic state of equipment development, presents an unusualy attractive situation for leasing rather than buying - the implications of the GAO report [7] notwithstanding.

C. The Competitive Position of Facsimile Relative To Other Services. To understand the competitive position of facsimile at present, the relative percentages of the U.S. expenditures for hard-copy communications that are held by facsimile and the other services must first be considered [14]. These percentages are presented in Figure 6 in terms of total dollar expenditures for each service during 1978.

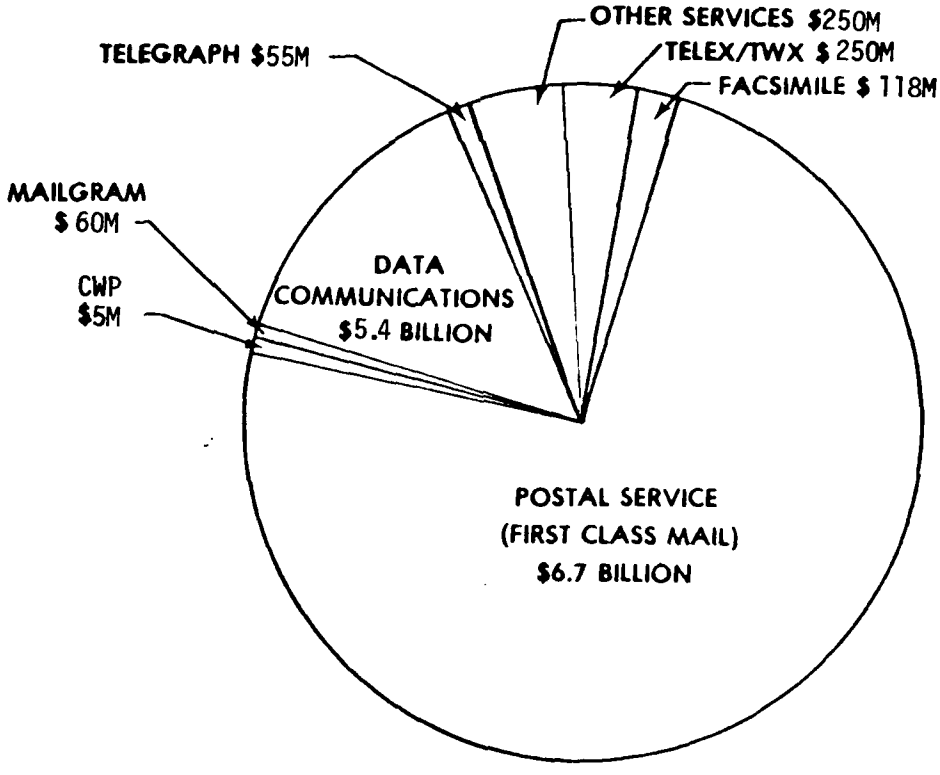


Figure 6. U.S. Expenditures on Hardcopy Communications - 1978

As to be expected, there is intense competition among the various telecommunications services, and between them and the Postal Service, with each having certain advantages and disadvantages. However, since cost per message transmitted is the dominant factor for selection among these competing services, it is interesting to compare the future cost trends projected for each service. Such a projection, as developed by Mr. Stephen Caswell of International Resource Development Corporation [8] and updated to reflect transmission costs and events since publication, is given in Figure 7 for a 10 year period. Telegraph, represented in Figure 6 with a market share of $55 million, is not represented in this projection since it seems to be a dying service that is losing out to other services such as Telex/TWX, Mailgram, and Faxgram.

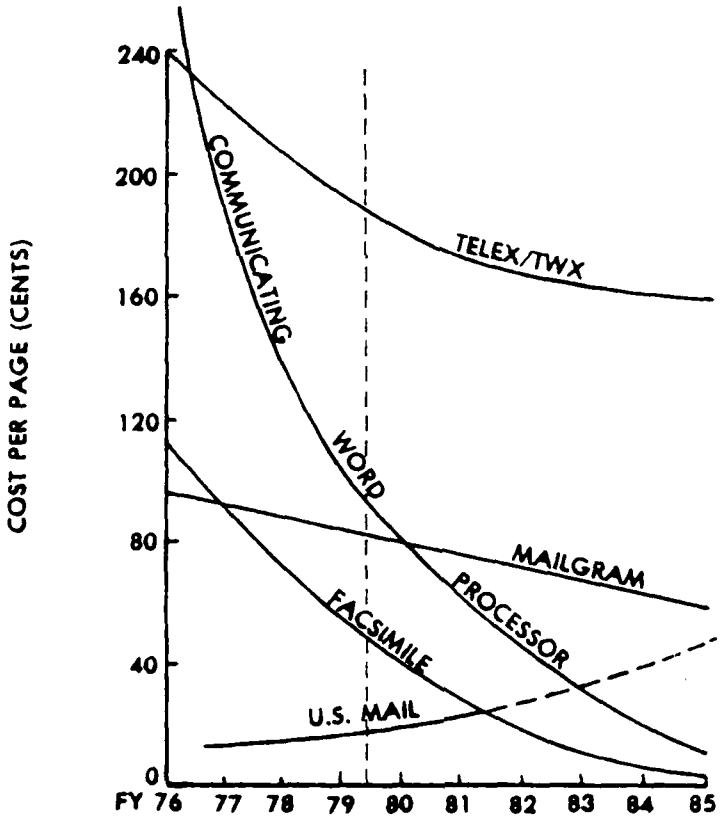


Figure 7. Cost Trends for the Major Hardcopy Communications Media

The cost trends exhibited in Figure 7, coupled with the percentages of the current market held by each service as depicted in Figure 6, clearly indicate that facsimile has a considerable potential for expansion. This picture is clouded only by the competitive position projected for the communicating word processor toward the end of the time period, which is expected to capture much of the strictly narrative facsimile market after the mid-1980's.

2. CURRENT AND NEAR TERM DEMAND WITHIN DOD

The demand for facsimile service within DoD is growing rapidly. However, the number of commercial facsimile terminals placed to date can only be estimated, since there is as yet no specific regulation requiring that commercial facsimile procurement actions be processed through a central authority such as DECCO - although the MILDEP's are encouraged to do so. This situation is compounded by the reluctance on the part of the facsimile terminal vendors to release placement figures that could be advantageous to a competitor. The following specific situations have been noted:

- One manufacturer's equipment placement list (not included due to its proprietary nature) shows a figure for Air Force placed equipment 10 times that depicted in the then current Air Force Facsimile Directory - indicating that the Air Force, as with the other services, is not aware of total equipment placements.

- Of approximately 200 to 300 digital facsimile terminals placed in DoD by DACOM up to the end of 1977, only 2 were directly terminated on AUTODIN. The remainder apparently were being used over the commercial or dedicated networks or AUTOVON.

To gain a better insight into DoD user needs for facsimile service, DCEC asked the Naval Ocean Systems Center (NOSC), in October 1977, to conduct a survey of the current and projected facsimile demand within DoD and related agencies. The approach taken by NOSC was to contact key Army, Navy, and Air Force operational and staff elements worldwide to survey the current usage of facsimile as seen by experienced staff officers and communicators; and to solicit their assistance in identifying future trends for facsimile use. The results of this survey are reported in reference [9] and summarized in Table II in terms of the average number of pages to be transmitted monthly worldwide during the next few years. Table III indicates the percentages of this traffic expected to be rush (R), classified (C) and multiple addressed (M).

The following additional observations concerning current needs can be made as a result of the NOSC effort:

TABLE II. EXPECTED NEAR-TERM VOLUME OF FACSIMILE TRAFFIC IN PAGES PER MONTH

		EUROPE	PACIFIC	CONUS	TOTAL
NEAR-TERM NEEDS	P	1160	151	5404	6715
	D	410	96	4553	5059
	N	3813	839	46,308	50,960
	ALL	5383	1086	56,265	62,734

P - PICTURES
D - DRAWINGS
N - NARRATIVE

TABLE III. DISTRIBUTION OF EXPECTED NEAR-TERM TRAFFIC BY TYPE OF SERVICE REQUIREMENTS

		EUROPE	PACIFIC	CONUS	TOTAL
NEAR-TERM NEEDS					
	R	42%	31%	27%	32%
	M	18%	12%	14%	15%
	C	62%	70%	38%	52%

R - % RUSH
M - % MULTIPLE ADDRESS
C - % CLASSIFIED

- There is a considerable need for an informal action officer-to-action officer narrative service to permit staffing of command actions before official release. Many users interviewed saw facsimile as a means of "getting around" the formalities of the AUTODIN network.

- In those cases where a facsimile network has been superimposed over an existing teletype network, teletype traffic has been reduced substantially in favor of facsimile due primarily to greatly improved operational and maintenance efficiencies.

- There is considerable expressed need for a "next-day-of-delivery" type service that is more responsive than ordinary mail, but does not require the much shorter delivery times or format restrictions currently specified for AUTODIN messages.

- Many users see the less expensive analog convenience facsimile terminal as a means of bypassing the inconvenience of existing on-base distribution systems.

These observations, together with the other NOSC findings, indicate that the current driving force for facsimile applications within DoD is to be found primarily in the following three areas:

- Enhanced ease and speed of coordinating and communicating ideas.

- Reduced need for specially trained equipment operators, as are required for teletype and other "data" type terminals.

- An increasingly favorable cost position for facsimile relative to more traditional communications services such as teletype and mail.

3. FUTURE FACSIMILE DEMAND IN DoD

The future demand for facsimile service within DoD can be considered from two viewpoints: 1) in terms of the expected growth in installed equipments, and 2) in terms of the total number of facsimile transactions expected to be generated. Since each viewpoint has its strengths and weaknesses with regard to the current availability of information and insight, each is developed in the following discussions and the results compared in order to arrive at a composite projection of future facsimile demand.

a. Projected Growth of the Installed Equipment. Table IV presents three different ten year projections for installed facsimile equipment. These projections are by three market research and consulting firms - International Resource Development Inc. (IRD) and the Yankee Group, both specializing in the facsimile market, and Mr. Charles Beaudette of Cape Associates - and

represent the only such projections currently available to DCEC. Although these estimates are now over three years old, it is interesting to note that Yankee Groups' "most likely value" of 185,000 for the end of 1979 is very close to the current facsimile equipment inventory estimated at 181,250 by reference [14]. This lends considerable credence to the Yankee Group projection, at least over the near term.

TABLE IV. GROWTH ESTIMATE FOR TOTAL In-PLACE FAX TERMINAL EQUIPMENT

Year	IRD	YANKEE GROUP			CAPE ASSOCIATES
		Best Case	Most Likely	Worst Case	
1977		159,000	140,000	125,000	206,000
78	245,000	198,000	161,000	138,000	256,000
79		241,000	185,000	151,000	311,000
80		294,000	212,000	167,000	378,000
81	337,000	352,000	245,000	184,000	459,000
82		440,000	281,000	204,000	
83		550,000	330,000	226,000	
84		687,000	386,000	251,000	
85					
1986	546,000				

In considering DoD's share of the total facsimile equipment market, no distinction is made in the current literature between DoD and other government applications including state and local governments. The IRD report [4] includes "Government" requirements with each specific commodity market without providing any insight into what that share is. The Yankee Group report [10], on the other hand, assigns "Government" 21 percent of the total market.

In order to clarify this issue, DCEC queried the major manufacturers regarding the percentage of their total business conducted with DoD. Given this figure and each manufacturer's percentage of the total market [4], as given in Table V, an estimate of DoD's share of facsimile terminals can be made. The results of the DCEC canvass are proprietary in nature and are not included in this report. These results indicate that DoD's share of the current market is approximately 8 percent and can be expected to remain between 5 and 12 percent for the foreseeable future.

TABLE V. U.S. MARKET SHARE OF GENERAL PURPOSE EQUIPMENT.

EXXON/QWIP	20
GSI/Burroughs	18
Infolink/Victor	<1
3M	13
Rapifax (DACOM)	3
Stewart Warner Datafax	<1
Telautograph	<1
Xerox	43
Panafax	1
TOTAL	100.0%

The projected number of installed terminals can be converted to an equivalent number of pages to be transmitted per day by multiplying the average daily volume in pages, for a typical terminal in each application category, by the number of terminals estimated for that category. The number of pages transmitted can then be converted to bits by assuming a typical resolution requirement and data compression ratio expected for each category. The calculations associated with this process are given in Appendix E. The results are depicted in Figure 8.

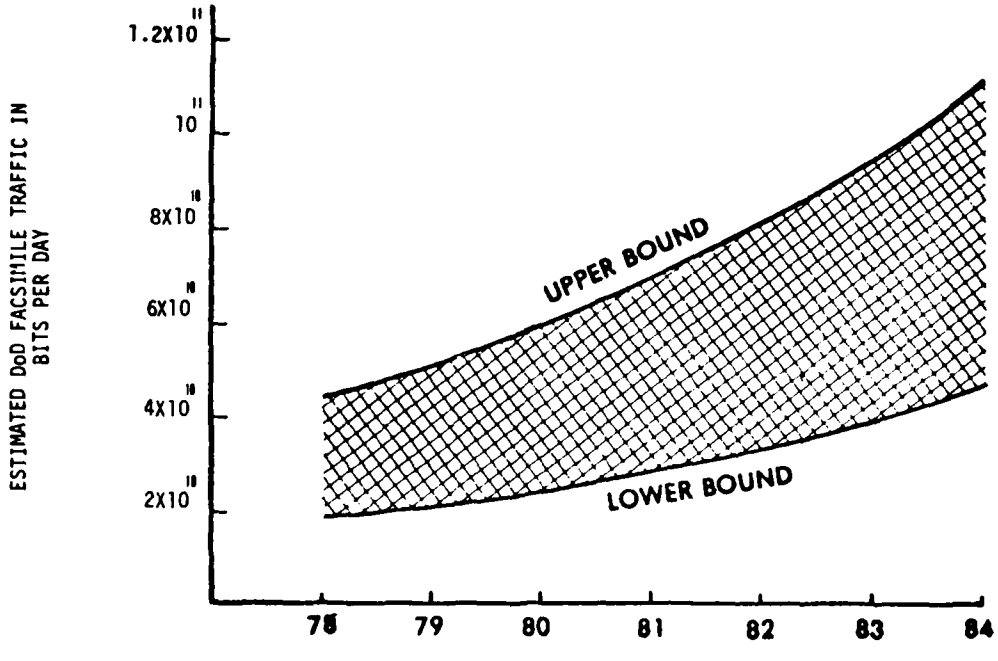


Figure 8. Projected Facsimile Growth in DoD

b. Projected Growth by Number of Transactions. There are currently two sources of information available for projecting the growth of DoD facsimile traffic in terms of transactional requirements rather than by an estimate of terminal growth. These sources are the "Facsimile User Survey" conducted for DCEC by NOSC [9], and the new IRD Facsimile Market Survey [14].

(1) The NOSC user requirement survey reported the best assessments of the staff officers and communicators interviewed regarding future trends in facsimile usage for their respective areas of interest. The numerical results of this survey, summarized in Table VI, together with the following observations obtained during the interviews, form the basis for the NOSC projection of future facsimile demand given in Figure 9. The calculations and supporting rationale for this figure are similar to those discussed in Appendix E applied to terminal growth.

- The quantitative data collected during the survey projects a tenfold increase in facsimile type traffic for the 1990 time frame.
- Past experience with field surveys indicates that most of the individual projections are more likely to fit within a time period of from 3 to 5 years, representing a latent demand that could be evident by 1985, rather than 1990.
- A large increase in data volume for all hardcopy services, including facsimile, will be generated with the introduction of electronic mail and other new office technologies in the 1985 time period.

(2) The most recent IRD market survey [14] provides an estimate of facsimile's future growth in terms of pages sent for the various categories of facsimile equipment, including both the business and the specialized segments of the market. These values are given in Table VII. The total number of pages transmitted can be converted to the number of bits to be sent by applying the same procedures used in converting the data obtained in the NOSC survey. Apportioning the results to reflect DoD use, however, is not so easy a matter. Lacking any additional insight, the five to twelve percent estimate used in the terminal growth projection is also used here. The resulting projection, in bits transmitted per day, is given in Figure 10. Again, the calculations supporting this figure are similar to those discussed in Appendix E for terminal growth.

The bend in the curve between 1982 and 1984 reflects a time period wherein data compression efficiencies are increasing at a more rapid pace than traffic growth. The resumption of a positive growth trend after this period indicates that the enhancements in data compression techniques are not able to keep pace with rising traffic demand and requirements for increased resolution resulting from wideband implementations.

TABLE VI. PROJECTED VOLUME OF FACSIMILE TRAFFIC IN *PAGES PER MONTH - 1985 (NOSC REPORT)*

		EUROPE	PACIFIC	CONUS	TOTAL
PROJECTED	P	3370	5685	6840	15,895
	D	34,940	5127	10,530	50,597
	N	8801	4475	95,051	108,326
	ALL	47,231	15,287	112,420	174,938

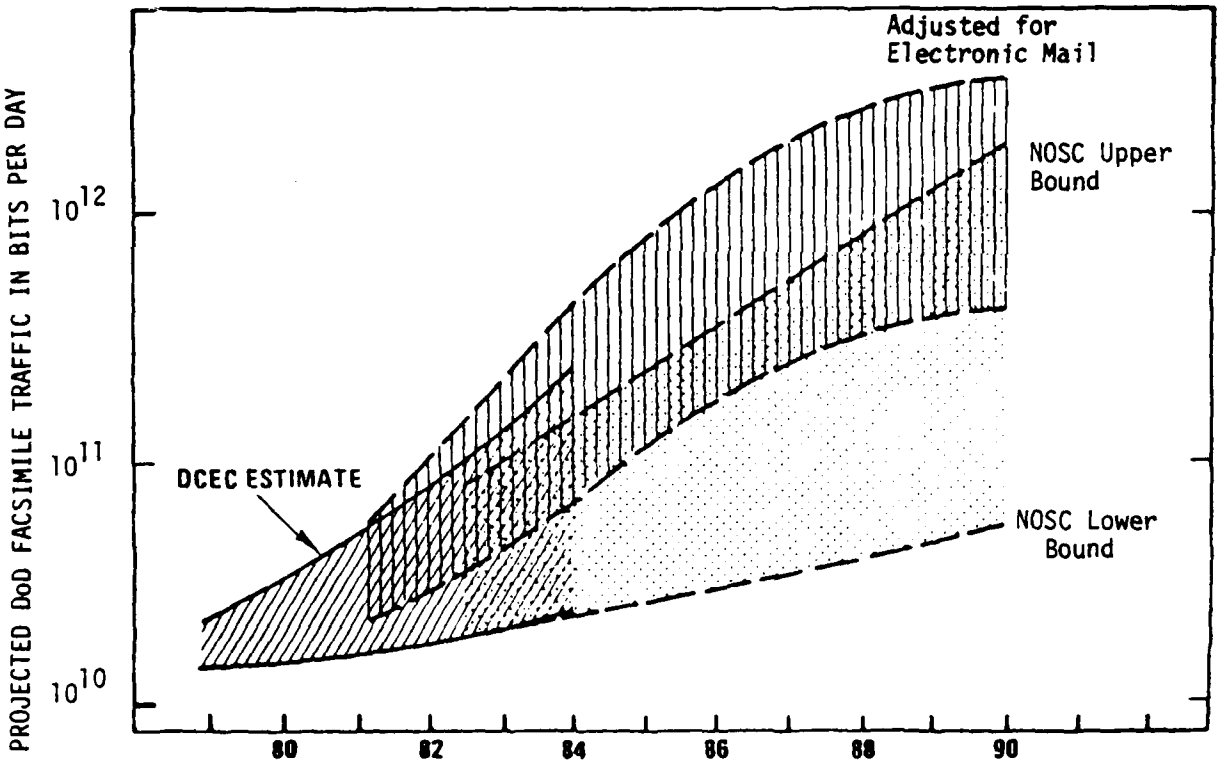


Figure 9. Projected Growth in DoD Facsimile Traffic - NOSC Report

TABLE VII. IRD PROJECTION OF THE GROWTH IN PAGES TRANSMITTED BY FACSIMILE IN MILLIONS OF PAGES PER YEAR.

FACSIMILE APPLICATION	1978	1980	1983	1988
Business				
Low Speed	29	39	32	30
Medium Speed	29	90	167	280
High Speed	50	130	255	190
Wideband	-	-	570	2,200
Specialized	106	112	122	135
TOTAL	214	371	1,146	2,835

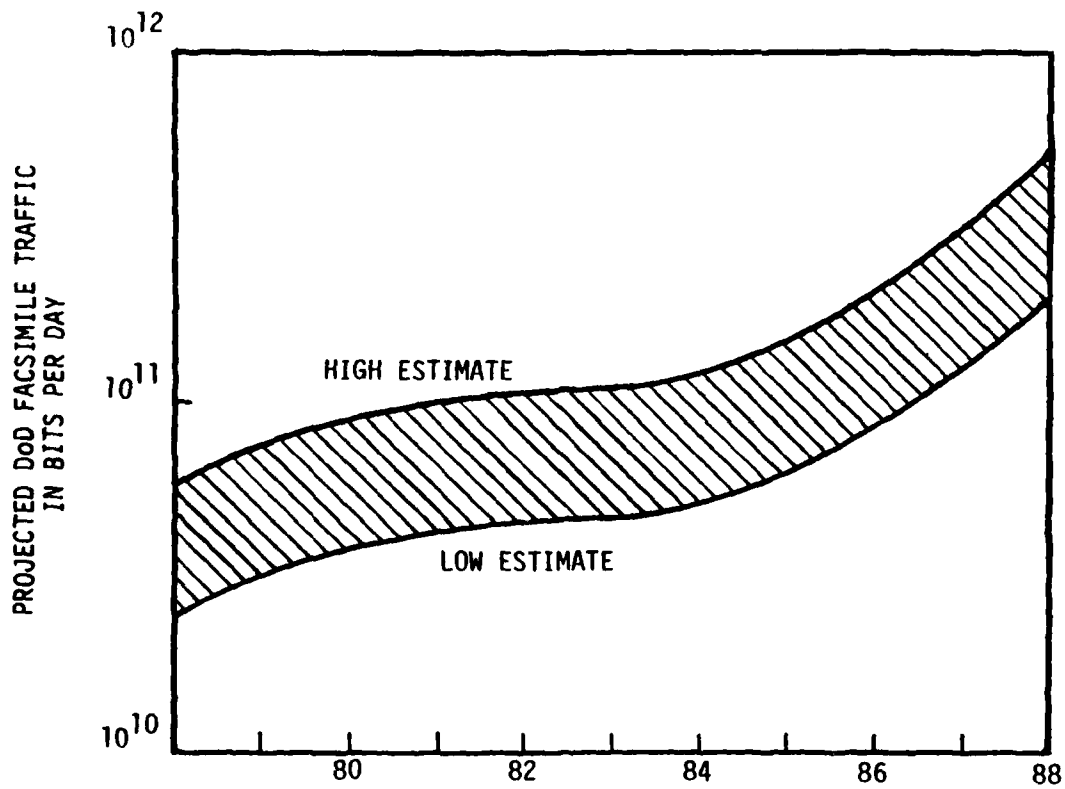


Figure 10. Projected Growth in DoD Facsimile Traffic - IRD Page Growth Projection.

c. A Composite Projection. The growth projections relating to the economy as a whole, while based on fairly definitive knowledge of market trends in the civil sector, do not reflect the impact of the Communicating Word Processor (CWP) toward the end of the 1980's and are difficult to relate to the military environment.

The growth projection based on NOSC's user requirement survey provides the best estimate of current use and perceived need. However, these insights are more near term than long range, and also do not reflect the impact of CWP's and other office telecommunications services which could be more effective than facsimile in the long run, at least for narrative type traffic.

With these observations in mind, a composite projection of future facsimile demand was developed and is presented in Figure 11. This projection is based on calculations similar to those in previous projections modified by the following premises:

- Due to the integrated nature of the military organizational structure, intra and inter service facsimile demand will grow faster than service between equivalent segments in private industry. This is reflected in the composite projection by assuming a 10 percent and 25 percent higher growth rate respectively for the low and high traffic estimates.

- Given the cohesiveness of a military installation relative to a typical business community, over-the-counter mail room service will play a much greater role than convenience facsimile for military applications. This is reflected in the composite projection by assuming a 50:42:8 ratio rather than a 70:22:8 ratio for the distribution of convenience, mailroom and special purpose terminals respectively.

- The demand for Electronic Mail is probably stronger in DoD than it is in the private sector, because of the global nature of the military establishment and the requirements of the intelligence community for high resolution photography and imagery transmission. This is reflected in the composite projection by assuming a higher relative growth ratio for wideband terminals than for either the medium or high speed terminal categories, and by assuming that the copy resolution objectives, as given in Appendix E (Table E-IV), are required one time period sooner for DoD users.

- The need to transmit large volumes of classified data will favor digital terminal equipment within DoD to a greater extent than for the private sector. This is reflected in the composite projection by assuming that the data compression ratios given in Appendix E (Table E-V) for the far term are implemented during the mid-term in DoD.

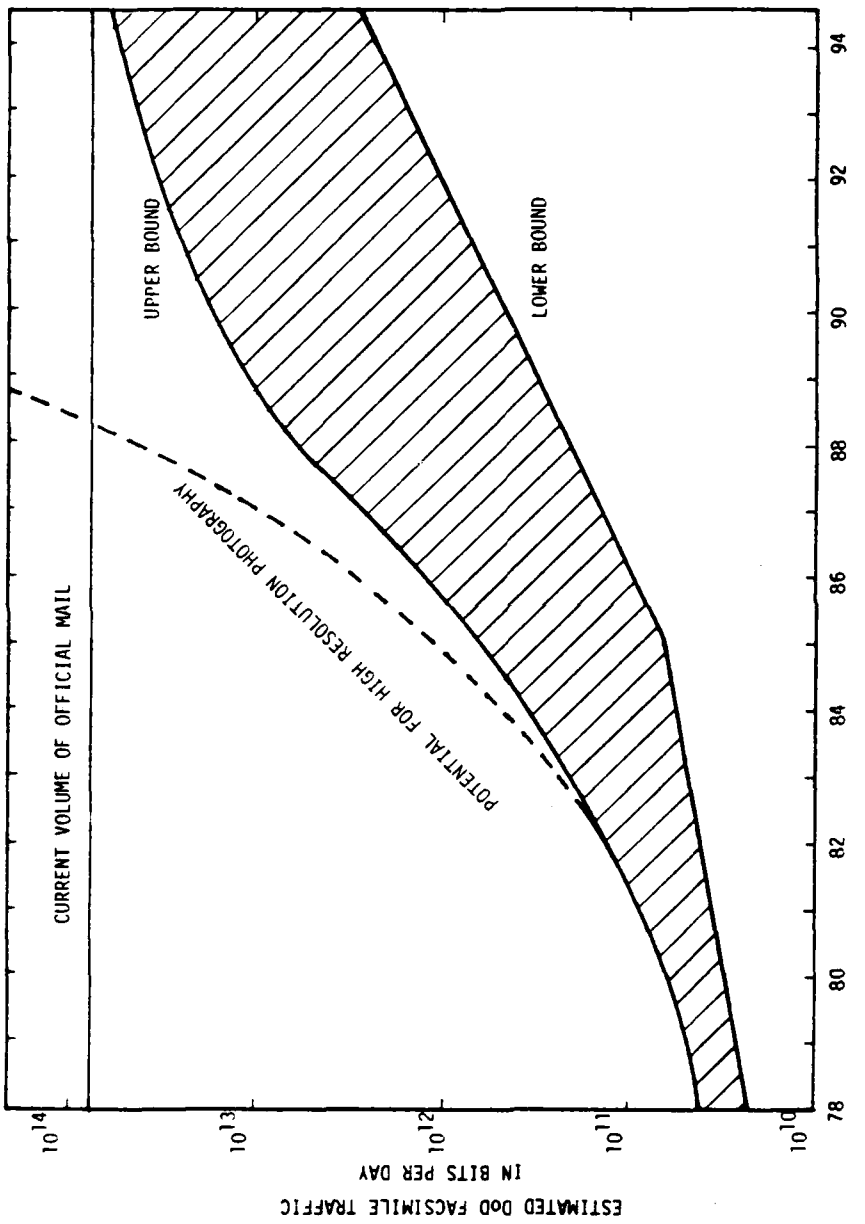


Figure 11. Composite DoD Facsimile Traffic Projection

- The Communicating Word Processsor will begin to appear in significant numbers by 1982 or 1983 and will continue to capture an increasingly larger share of alphanumeric transmissions until facsimile's share of hardcopy communications is reduced to less than 10 percent by 1990.

Figure 11 contains two projection curves: a "low estimate", which assumes that growth will occur in all facsimile application areas, but at a rather conservative rate; and a "high estimate", which is based on the assumption that we are on the brink of an information revolution that will result in tremendous growth in new and innovative applications for hard copy information transfer. The "high" trend is expected to begin slowing down by the mid-1980's, reflecting price parity of facsimile with the communicating word processor. Growth will then tend asymptotically toward an upper limit of 8×10^{13} bits per day in recognition that there is a limit to the amount of hardcopy information that can be absorbed by a finite DoD population (assumed for this purpose to be about 3 million persons). This limit approximates an amount of traffic equal to the total current volume of DoD official first class mail. Although a significant portion of official first class mail may never be subject to electronic mail service, this amount should be more than offset by the addition of draft material for the purpose of coordination which is not currently transmitted at all.

Finally, whereas a large growth factor is projected for facsimile service, the corresponding network capacity needed to support this demand is not expected to grow as rapidly, due to the development of more efficient data compression and image recognition techniques. However, it should be noted that this projection does not fully address high resolution intelligence requirements for which an adequate estimate is yet to be obtained. Efforts are currently underway to obtain this information and the findings could have a considerable impact on the traffic projected.

IV. TECHNICAL ISSUES

I. INTRODUCTION

The facsimile process consists basically of converting the visual detail of an original document, diagram, photograph, etc., to an analogous electric current; conditioning the current for transmission by wire or radio to a receiver; restoring the transmitted signal to its original form; amplifying it; and converting the amplified signal to a hard copy facsimile of the original document. In practice this process is generally divided into the following five functions for analysis purposes: scanning, recording, amplification, phasing and synchronization, and transmission.

In this report, how facsimile works is treated only to the extent necessary to evaluate the impact of facsimile on the DCS and to appreciate the future developments which may enhance facsimile's desirability as a telecommunications service. A more detailed treatment of the technical aspects of facsimile can be found in [3].

The impact of facsimile on the subsystems of the DCS is primarily concerned with circuit or switch utilization time, which depends mainly upon the characteristics of the facsimile transmission and the number of transmissions placed on the network. The first consideration is related to the quality expected of the received copy and the efficiency with which the transmission assets are utilized. The second consideration has already been treated in Section III - THE DEMAND FOR FACSIMILE SERVICE.

2. COPY QUALITY

The quality expected from the received copy is a variable which is subjective in nature and cannot be computed or predicted with mathematical precision. Accordingly, quality is first addressed in terms of the factors determining facsimile's technical capacity to respond to a stated service need, and then from the viewpoint of the user who must relate that need to the level of resources he is willing to commit (or pay for). A brief discussion of how facsimile differs from other hardcopy telecommunications services in its response to transmission impairments is also provided.

a. Relationship Between Quality and Circuit Utilization Time. Copy quality is primarily determined by the resolution and contrast selected for transmission: impariments due to digitizing (in the case of digital equipment); and distortions caused by phasing and synchronization errors, mismatched indices of cooperation, and the various phenomena inherent in the transmission media itself. All must be considered by the user when selecting equipment for his particular application. However, the selection of resolution and contrast have by far the major impact.

(1) Resolution. Resolution is the degree to which adjacent elements of an image are distinguishable as being separate. In scan systems, resolution is specified by the scan density or number of scan lines within a given linear dimension - usually expressed in terms of lines per inch (LPI) or lines per millimeter (LPM).

In facsimile scanning systems, there are two sets of resolution variables: one set addresses the resolution along the scan line, which is governed by the linearity and tonal sensitivity of the electronics; and the other set addresses the resolution at right angles to the scan line, which is controlled essentially by the speed of the document through the machine. Thus, the resolution that can be achieved with a particular piece of equipment is generally dependent upon the complexity, hence the cost, of that piece of equipment.

The relationship between resolution and channel utilization time for uncompressed data transmission is shown in Figure 12 for a standard 8-1/2 x 11 inch page. Note that the increase in transmission time at a given data rate is approximately equal to the square of the increase in resolution.

(2) Contrast. Contrast is the degree to which the tonal values of the image being transmitted are reproduced. In analog facsimile systems, where the amplitude of the transmitted signal is generally proportional to the tonal value of the element being transmitted, the range in contrast is continuous within the band limitations of the transmission channel. For digital facsimile equipment, however, the tonal subtleties detected by the scanner must be digitized into discrete levels, referred to as gray scale levels, prior to transmission. The degree to which contrast is recognizable in digital transmission ranges from a strictly black/white representation, for the less expensive equipment which utilizes 1 bit pulse code modulation (PCM) techniques, to a degree equalling or even surpassing analog quality for more expensive equipment utilizing 16, 32 or even a higher number of gray scale levels.

Figure 13 summarizes the relationship between contrast and channel utilization time for uncompressed digital transmission. Note that although this increase is much more rapid than for resolution at the earlier stages of expansion, it tends to level off, whereas resolution continues to increase at an expending rate. There is substantial evidence that for a given level of legibility, resolution and contrast can to some extent compensate each other [3]. The apparent reason is that increased brightness causes a corresponding decrease in the size of the eye's iris, which results in improved resolving capability. Empirical data correlating contrast and resolution are available from two studies by Dr. C. E. Nelson [12] and H. C. Frey [3] which indicate that contrast may influence legibility to an even greater extent than does resolution. These tests are of limited scope, however, and cannot be considered as conclusive. Suffice it to say that a relationship does exist between resolution and contrast and that contrast

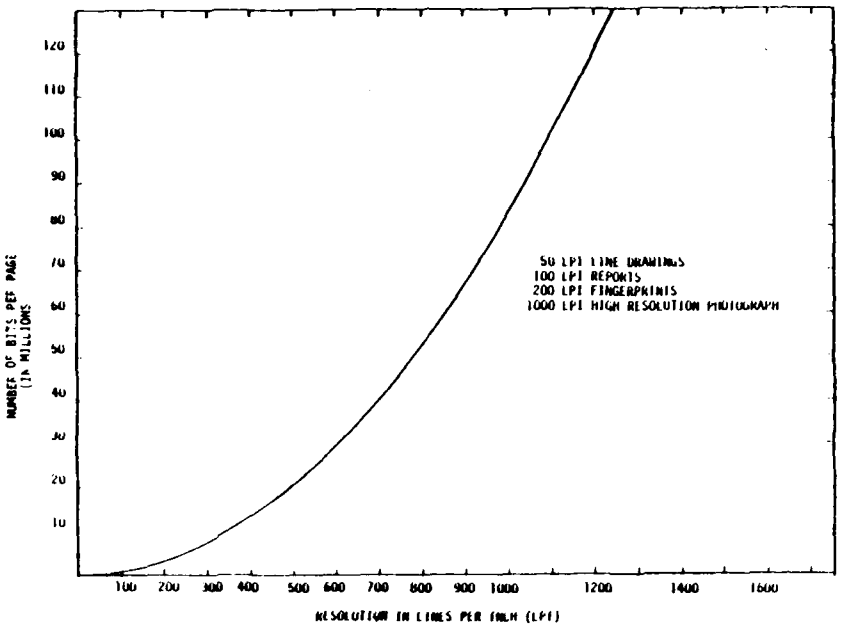


Figure 12. Effect of Increasing Resolution on Bits Transmitted (uncompressed)

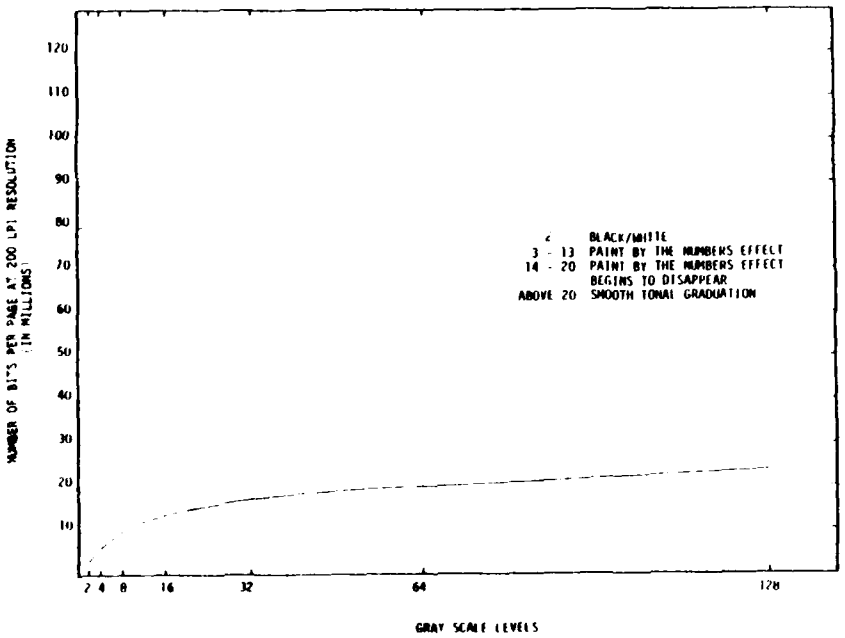


Figure 13. Effect of Increasing Contrast on Bits Transmitted (uncompressed)

may be a more effective means for obtaining quality enhancement than resolution for many applications, especially in analog systems.

b. Criteria for Determining Quality Needs. In many applications today, the user states his requirement in terms of "lines per inch" and the number of gray scale levels desired, rather than giving a more definitive specification of legibility desired. This, in essence, is stating a solution rather than a need and is too often based on "sample" copy experiences. An understanding is needed of the differences between inadequate resolution/contrast and other impairments, such as paper quality, lack of satisfactory synchronization, etc., which vary with the machine and are not improved by increasing either resolution or contrast. Due to the considerable impact that both resolution and contrast have on transmission time, a discussion of legibility and pictorial criteria is included in Appendix A. This discussion should encourage the proper statement of facsimile service needs and aid in the proper selection of machine options.

c. The Effect of Transmission Impairments. Facsimile can be transmitted over either a voice or a data grade channel and is subject to the same problems as encountered by other hardcopy telecommunications services. Facsimile's response to the following transmission impairments, however, is significantly different than for either voice or data:

(1) For Analog Systems:

- Crosstalk

  Whereas crosstalk in a voice system is merely a nuisance, it causes blemishes in the received facsimile copy and may result in the need for a complete retransmission in a facsimile system.

- Single-frequency AC Interference

  This type of interference is usually continuous and symmetrical resulting in a herringbone or diagonal stripe pattern over the entire facsimile recording.

- Level Fluctuations

  Fluctuations in transmission level can occur for a variety of reasons, some of them associated with intrinsic characteristics of long telephone circuits, while others are due to natural phenomena beyond human control. These abrupt changes in transmission loss are generally small enough to go unnoticed in voice communications, but are sufficient to visibly blemish a facsimile recording.

- Echo

The effects of echo on a facsimile recording are similar to the effect on a TV transmission by causing the appearance of ripples or "ghosts" in the received copy.

- Delay Distortion

The effect on facsimile is similar to that of ECHO except that it produces more of a smear than a ghost and may not manifest itself uniformly throughout a recording.

(2) For Digital Systems:

- Quantization Noise

There are two potential impairments inherent in the analog-to-digital conversion process. One is the possibility of errors in discrimination between one tonal level and another. The other is the displacement of marks that may occur in the recording due to slight differences between the scan rate and the digital sampling rate.

- Pulse Jitter

Jitter is an effect occurring at right angles to the scan axis of a facsimile recording and can result in a slight time wiggle or spatial offset in the vertical dimension.

- Error Performance

Two-level digital facsimile in the uncompressed mode is considerably robust in a high error environment, and can produce recognizable narrative or simple graphic copy when all other forms of telecommunication produce only garble. However, when the redundancy inherent in a normal facsimile transmission is removed by data compression to improve transmission efficiency, error performance degrades significantly to that more characteristic of teletype or other data services.

3. TRANSMISSION EFFICIENCY

Whereas it would take approximately 1500 bits and less than 2 seconds to transmit this page by teletype at 9.6 kb/s, it would take a facsimile machine operating without compression at the same rate and a resolution of 100 LPI almost 2 minutes to transmit the same page. The difference lies in the fact that facsimile transmits every element on the page, whether it contains desired information or not. Thus, it is readily apparent that techniques designed to

reduce this redundancy can have considerable impact on the efficiency with which facsimile utilizes the transmission media and the related cost of facsimile operation.

A number of data compression techniques are currently available for use with facsimile, and more are being developed. They all serve to reduce the number of bits that must be sent in order to reconstruct the document image at the receiving end. These techniques range from simply scanning the white areas of the page at a much higher rate then the blacks, to full image or character recognition. In between lie the more common single line run-length codes and the more complex block codes favored by the Japanese for tansmitting their kanji (Chinese) characters. The application of these techniques implies digital operation, since compression techniques providing ratios greater than 2:1 have yet to prove effective for analog application. Typical compression ratios achievable with current coding schemes are given in Table VIII. The high value given for FAX-COMP has not yet been confirmed by independent authority but is considered reasonable in that FAX-COMP uses an adaptive hybrid OCR/FAX compression algorithm and is acting essentially as an OCR device for alphanumeric transmission.

Which code to select for a particular application depends on the type of copy being transmitted and the transmission media. In particular, the relative efficiency of single line run-length and multiple line block codes, based on the probability of occurrence for specific image patterns, varies widely for different types of copy. In the extreme, high resolution photographs may take just as long or longer to transmit using current compression techniques than conventional methods. A solution to the problem of a variety of image document types, seems to be the use of adaptive coding schemes which "build" the coding dictionary independently for each transmission. These techniques are currently employed in the FAX-COMP device and are under further development by WONG [13] and others. In addition, compression techniques being developed for video application with efficiencies on the order of 1/2 to 1/4 bits per picture element have been reported, and are equally applicable to high resolution photographic applications.

In the case of a "noisy" transmission environment, such as could be encountered in the tactical world, just the opposite set of considerations exists. Here, the very redundancy of facsimile renders it preferable to teletype or other coded data transmission techniques for which a single "hit" can drastically alter the information being sent. In this application, the compresssion technique used will be a compromise between efficient circuit utilization and error rate performance.

The discussion above applies primarily to those cases where resolution is the only consideration. However, when contrast is considered, it is not always desirable to compress gray scale levels because errors in transmission will perturb the received signal and may compromise tonal fidelity of the recorded copy. In addition, compression techniques which address both

TABLE VIII. COMPARISON OF COMPRESSION EFFICIENCIES FOR CODING OF CCITT DOCUMENT SET WITH VARIOUS CODING ALGORITHMS

DESCRIPTION	MODIFIED HUFFMAN CODE CCITT 1-D	KALLE-INFOTEC CODE RAPICOM	KDD CODE (1977)	TUH-CODE 4 PEL PREDICT-IVE CODER	KDD ILC CODE	FAX-COMP TOTAL BLOCKING	FAX-COMP BLOCKING/ RESIDUE
BUSINESS LETTER	16.5	15.6	19.7	24.7	27.0	54.4	54.7
CIRCUIT DIAGRAM	16.3	20.9	28.7	29.0	39.7	27.4	37.2
DETAILED INVOICE	9.4	10.0	12.1	15.0	17.0	25.8	29.7
JOURNAL PAGE (FRENCH)	5.8	5.3	5.4	7.5	7.5	19.9	22.7
JOURNAL PAGE WITH FIGURES	9.2	9.4	11.0	13.8	15.4	26.2	29.3
INTRICATE FIGURE	11.0	13.0	17.5	20.0	25.6	19.9	24.2
JAPANESE (SMALL PRINT)	5.2	5.0	5.4	6.6	7.5	9.9	11.3
HANDWRITING LARGE WHITE LETTERS ON BLACK BACK-GROUND	8.7	12.0	14.7	15.0	21.4	10.4	16.8

resolution and contrast are very complex and have yet to be developed on a practical basis. The complexity required of these schemes, together with the reduced effectiveness of data compression for higher density applications, are expected to limit the practical application of data compression to applications where gray scale is not a major concern.

4. EQUIPMENT COMPATIBILITY

Equipment compatibility refers to the ability of one facsimile equipment model to communicate with another facsimile equipment model regardless of the manufacturer. Compatibility can be either full compatibility or partial compatibility wherein communications exchange can take place but at reduced effectiveness. The factors necessary for full or partial compatibility, together with a brief overview of the current compatibility situation among the various manufacturers and the status of the DoD standards program, are provided in the following discussion.

a. Technical Requirements for Compatibility. Different facsimile designs, regardless of whether analog or digital, must have the following in common for full compatibility: index of cooperation, vertical resolution, protocols, speed of operation, modulation/demodulation technique, and copy length (drum equipment). In additon, equipment-compatible AD/DA techniques and, where data compression is used, a common compression algorithm and dictionary are required for digital equipment. For gray scale transmission, tonal fidelity must also be added to the list. Table IX lists the compatibility requirements for the different modes of facsimile transmission.

The most important feature in determining full compatibility is the index of cooperation, which is the product of scan density times effective stroke length. For drum equipment, the index of cooperation is determined by the drum diameter and the equipment resolution in lines per inch. If a transmitter and receiver have the same index they are considered compatible, other features being equal, and the recording produced at the receiver will be a geometrically faithful reproduction of the subject copy transmitted, although not necessarily of the same size. If the indices are different, distortion will appear in either or both dimensions depending on the mismatch.

Protocols needed to perform the "hand shaking" between transmitter and recorder have to be common for the system to operate. Normal controls exercised by the facsimile transmitter over the recorder are start, phase (synchronize), level set, run, and stop. Additional controls that can be exercised by the transmitter include the selection of gray scale, resolution, and speed of operation.

Speed of operation, expressed in terms of lines per minute, revolutions per minute, or bits per second, must be common to prevent skew in the recorded copy. Constant velocity machines are phased (synchronized) at the

TABLE IX. COMPATIBILITY REQUIREMENTS FOR DIFFERENT MODES OF FACSIMILE TRANSMISSION

MODE OF TRANSMISSION	INDEX OF COOPERATION	VERTICAL RESOLUTION	PROTOCOLS	COPY SIZE	MODULATION/DEMODULATION	AD/DA CONVERSION	SPEED OF OPERATION	COMPRESSION ALGORITHM AND DICTIONARY	TONAL RANGE
BLACK & WHITE ANALOG, CONSTANT VELOCITY	X	X	X	X	X		X		
BLACK & WHITE, 1 BIT PCM, CONSTANT VELOCITY	X	X	X	X	X	X	X		
BLACK & WHITE, 1 BIT PCM, COMPRESSED CONSTANT VELOCITY	X	X	X	X	X		X	X	
BLACK & WHITE, 1 BIT PCM, COMPRESSED, VARIABLE VELOCITY	X	X	X		X		X	X	
GRAY SCALE (CONTINUOUS TONE) ANALOG, CONSTANT VELOCITY	X	X	X	X	X		X		X
GRAY SCALE (CONTINUOUS TONE) DIGITAL, CONSTANT VELOCITY	X	X	X	X	X	X	X		X
GRAY SCALE (CONTINUOUS TONE) DIGITAL, COMPRESSED, CONSTANT VELOCITY	X	X	X	X	X		X	X	X
GRAY SCALE (CONTINUOUS TONE) DIGITAL, COMPRESSED, VARIABLE VELOCITY	X	X	X		X		X	X	X

beginning of the transmission and rely on stable sources in both the transmitter and recorder to keep them synchronized for the duration of the transmission. Variable velocity systems operate on a line-by-line basis and generally synchronize after each line transmitted. Variable velocity machines are generally associated with digital facsimile operating in the compressed mode.

Copy size becomes important when the transmitted "original" is larger than the capabilities of the received terminal. For flat bed machines, copy width is limited while copy length is generally unlimited for roll fed machines. Drum recorder copy size is limited in both dimensions.

For digital equipments, the analog-to-digital/digital-to-analog (AD/DA) conversion technique must be the same for both transmitter and recorder. This is also true for the compression algorithm and dictionary when operating in the compressed transmission mode.

Tonal range, or the dynamic range of the recording media, must be capable of reproducing the dynamic range inherent in the transmitted signal or the gray scale reproduction will be severely compromised or negated.

Finally, the modulation/demodulation schemes used for both the facsimile transmitter and recorder must be compatible in order for the facsimile receiver to detect and record the transmitted signal.

b. Compatibility Among Current Equipments. There currently is full compatibility within the United States and Canada among most analog facsimile equipment operating at the 4 to 6 minute speeds (CCITT Group I machines). However, compatibility among U.S. manufacturers of digital facsimile equipment, and between U.S. manufacturers and the rest of the world for all other equipment, continues to evolve on an ad hoc basis. The CCITT has established preliminary recommendations for 2 to 3 minute and sub-minute transmission rates; however, these have not yet been adopted by the U.S. Electronics Industries Association (EIA) and, therefore, are not binding on U.S. manufacturers. Currently, a significant amount of equipment installed in the U.S. operating at the 2 to 3 minute speeds does not comply with the proposed CCITT standards. With over 20,000 of these units in service in the U.S., a rapid changeover cannot be expected. This indicates that the likelihood of full compatibility with Europe and Japan in the near future is unlikely.

The situation at the sub-minute digital rates is even worse, since there are now at least three different maufacturing standards within the U.S. This situation is expected to continue until the emergence of large Electronic Mail Systems, which are expected to gradually lead to a single U.S. standard in full compliance with the international standard as finally adopted.

c. Facsimile Standards Issues in DoD. The standards issue within DoD is primarily centered around the differing approaches taken by NATO, TRI-TAC, and the commercial world. NATO, initially opting for the adoption of the CCITT recommended standard, is now changing its position towards that of TRI-TAC, which maintains that certain aspects of the situation are unique to the tactical world.

DCA has attempted to bring the various parties together by developing a draft Military Facsimile Standard, which has been staffed through TRI-TAC and the MILDEP's. This standard is directed primarily at digital operations, although the analog aspects of facsimile transmission are also addressed.

It is expected that the draft standard, as modified, will eventually be approved within DoD. Meanwhile, however, several issues remain to be resolved. These issues primarily relate to the scan characteristics, signaling protocols, data compression scheme, and error protection techniques to be adopted. A more detailed discussion of these issues is given in Appendix B.

5. TRENDS IN FACSIMILE TECHNOLOGY

The following issues are involved in reducing the cost of facsimile equipment or enhancing its operational desirability: improved image quality, increased paper economy, more efficient compression techniques, and the addition of more flexible operating features.

The technologies required to address these issues for the main subdivisions of facsimile equipment are examined in Appendix C, both from the viewpoint of current limitations and the trends that may be expected for future equipment development. The results of this review are summarized in Figure 14 in terms of the potential for reducing facsimile terminal costs. This part of the report draws heavily on the IRD Market Analysis of Facsimile [4] and from the insights provided by Messrs Ken McConnell, Dave Shaler, and Charlie Beaudette at the IGC Facsimile Conference [6].

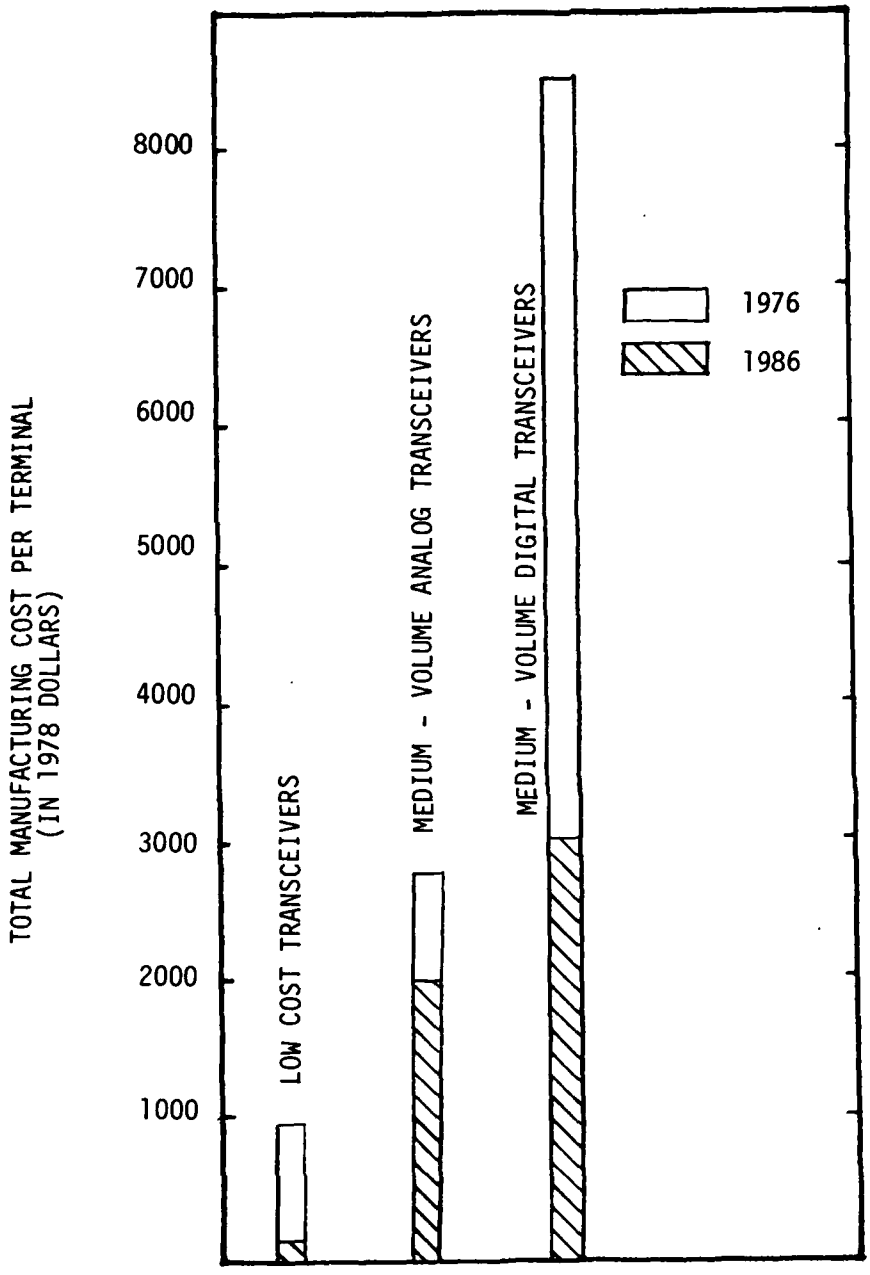


Figure 14. Trends in Facsimile Terminal Manufacturing Costs: 1976-86

V. IMPACT OF FACSIMILE ON THE DCS

1. INTRODUCTION

It is obvious from the previous sections of this report that facsimile has a tremendous potential for impacting the DCS. In many cases, this impact appears to be negative from the viewpoint of the network manager. On the other hand, the needs of DCS users for hard copy transfer have only partly been met by today's common user telecommunications network, oriented as it is for comm center-to-comm center rather than user-to-user service. In the past, the high cost of military communications relative to other resources provided little justification for additional assets to extend the hardcopy communications network to the immediate vicinity of the user. However, with today's decreasing terminal costs and rapidly increasing personnel costs, the user is buying or leasing the cheaper, less efficient terminal devices as office equipment and operating them at his desk. When faced with the problem of how to interconnect with the communications networks, he is taking the only choice he feels open to him - acoustic coupling via the telephone.

Because of this situation, and because the communicator is gradually losing control over the options being selected by the user, facsimile's impact on the DCS is examined both from the viewpoint of the network manager and the viewpoint of the user in the following discussion.

a. Systems Impacted. Five different communications approaches are potentially open to the DCS facsimile user: AUTOVON (including secure voice), AUTODIN I, AUTODIN II, commercial service, and dedicated point-to-point DCS circuits. The interrelationships between the categories of facsimile application, defined in Section II of this report, and the four approaches which involve the DCS are depicted in Table X and discussed in the following paragraphs.

(1) Desk Top Facsimile. Access to the communications network for desk top FAX users is primarily via the public dial network or AUTOVON. Direct access to AUTODIN I is precluded due to the low volume/low cost demand function characteristic of this application. However, use of the public dial system for local calls with a dial-up access to AUTODIN I for conversion to high-speed digital long distance transmission is considered technically feasible and is discussed further in the Report.

Desk Top FAX accessing the secure voice network either via an acoustic coupler or a data adapter could provide a secure service for transmitting classified information at very low volume levels. However, since the cheaper equipments utilize arc-type recording processes which will not pass TEMPEST criteria, the cost benefits of this approach may be negated by the need for more expensive terminal designs.

Direct access to AUTODIN II, as currently planned, will be limited to dial-in (send) only with no provision for a dial-out (receive) capability.

(2) Centralized Convenience Facsimile. At the lower to mid-volume levels, this application would be supported in a manner similar to that discussed for desk top FAX. At the high volume levels, the question of whether AUTOVON or AUTODIN I is the most cost effective solution becomes a major decision factor. Due to the operational burden placed on the user, especially for the more lengthy transactions, the traffic volume for centralized convenience applications is not expected to grow significantly until the mid-1980's when communicating office copiers will provide a more responsive alternative to facsimile operations.

(3) Mailroom Facsimile. With this application, facsimile becomes an operational service to the organization as a whole and becomes operationally, as well as administratively, integrated with the other communications services. The two key questions to be answered in implementing this application are whether to use analog or digital equipment and whether to approach AUTOVON, AUTODIN I, or the commercial networks for service. With the implementation of AUTODIN II and the achievement of price parity between analog and digital terminal equipments, both expected in the early 1980's, the operation of mailroom FAX will most likely become more attractive over this subsystem than over either commercial networks or AUTODIN I. The main issues to be addressed are treated separately for each of the candidate subsystems in the following sections.

(4) Wideband Facsimile. As the volume of facsimile operation grows and extensive electronic mail service materializes within DoD, a point will be reached where neither AUTOVON nor AUTODIN I provides a cost effective solution. This point will occur when the current switched subsystems can no longer effectively support the data rates necessary to satisfy facsimile demand. Two major questions are raised: First, what is the proper systems architecture to support an extensive Electronic Mail Service (EMS), and second, can AUTODIN II handle the added demand or will it act merely as a major transitional phase to a new and improved system design? Both of these questions will be addressed by DCEC in the follow-on study effort and the results provided in a subsequent report.

Although electronic mail is not expected to pose a major problem for the DCS for another 4 to 5 years, the situation is considerably different for the other major subdivision in the wideband facsimile category - High Resolution Photography (HRP). HRP, in support of the intelligence community, is considered to have a potential for major impact on the future DCS. The requirements for HRP, for the most part, cannot be effectively met in the current switched subsystems due to the high data rates required to achieve the needed resolution and contrast.

Impact on the current wideband transmission system as a result of dedicated circuit solutions is difficult to evaluate, due to the sensitivity of the analysis to the geographical distribution and the lack of sufficient insight into the anticipated level of demand. The final solution

for this application area will most likely be provided by the wideband switched system to be developed in support of electronic mail. In this regard, DCEC with the aid of Headquarters, DCA, will attempt to gain a better insight into the needs of the Intelligence community in the follow-on effort. The results of this study will be provided in a subsequent report.

(5) Special Purpose FAX. Special purpose facsimile applications are generally satisfied in the current DCS by the use of dedicated or special purpose circuits. A list of these applications taken from the current DCA circuit data base is contained in Appendix D. Although an evaluation of each of these systems is beyond the scope of this report, each will be investigated in the follow-on effort to determine its unique communications needs. Many of these applications will benefit from the enhanced capabilities of the switched subsystems as they are expanded to support the growing general purpose facsimile requirement. In addition, as indicated in Section III, the trend in special purpose facsimile applications for the country as a whole, while still growing, is being completely overshadowed by developments in the general application area. This situation is considered to be equally true for DoD.

TABLE X. INTERRELATIONSHIP BETWEEN CATEGORY OF FAX APPLICATION AND THE SUBSYSTEMS OF THE DCS

	AUTOVON (Secure Voice)	AUTODIN I	AUTODIN II	COMMERCIAL	POINT-TO-POINT DEDICATED
DESK TOP FAX	P	S	S		
CENTRAL CONV. FAX	P	S	S		
MAIL ROOM FAX	P		P	S	
WIDEBAND			S	P	P
SPECIAL PURPOSE	S	S	S	P	P

P = Primary impact

S = Secondary impact

b. Current Policy Guidance. The current policy guidance concerning the use of facsimile over the military voice networks is primarily contained in a JCS document. A similar policy specifically addressing facsimile use over AUTODIN does not exist. The JCS guidance basically states that:

- The precedence level for common user facsimile transmission shall not exceed ROUTINE.
- Non-common user facsimile transmission will normally not exceed a continuous transmission time of 18 minutes nor a total transmission time of 1 hour during normal business hours on any one day. However, non-busy hours can be utilized to the maximum extent possible.
- Facsimile equipment will be equipped with an automatic disconnect feature which will free the circuit after the device is inactive for a period of 1 minute. However, exceptions to the automatic disconnect policy may be requested.
- Because of TEMPEST problems and the limited availability of wideband trunking, facsimile transmission over AUTOSEVOCOM is prohibited without prior approval by appropriate authority.
- Recent efforts to further develop operational guidance for the application of facsimile, while not yet approved, have been less restrictive in flavor but emphasize AUTODIN rather than AUTOVON for facsimile usage and attempt to establish "universal" standards for all DoD users, including the tactical community.

The question of management control of facsimile equipment for use within DoD varies from the Navy, which has officially declared facsimile to be classed as "office equipment", to the Army, which appears to be moving in the direction of centralized management control within the communications activities. Both extremes pose problems for the DCS. Centralized equipment management control within the communications community will tend to restrict the full potential of facsimile for user applications, while a completely open policy makes user requirement identification and evaluation in support of network design much more difficult.

The GAO has tended to take the centralized viewpoint in its report [7]. The report concludes with the following recommendations:

(1) "We recommend that the Administrator of General Services and the Secretary of Defense:

- Identify all facsimile equipment owned or leased by executive agencies, determine usage, and use such data to evaluate the need for existing and additional facsimile equipment.

- Encourage strongly the use of common-user or shared facsimile equipment, if appropriate.

- Determine periodically which facsimile machines are more economical to purchase and insure that they are purchased rather than leased.

- Reemphasize the need for agencies to consolidate their facsimile procurements and, where the aggregate exceeds the Federal Supply Service, have the Defense Commercial Communications Office or the military services attempt to negotiate a better price with the supplier.

(2) We further recommend that the Secretary of Defense:

- Instruct all DoD components to lease facsimile equipment through DECCO.

- Reevaluate the Joint Chiefs of Staff guidance, which requires the installation of automatic disconnect devices, which are not always needed."

The following comments are offered to place the issues raised in this section in a better perspective.

- JCS guidance states that AUTOVON and AUTOSEVOCOM will "handle essential command and control, operations, intelligence, logistic, diplomatic, and administrative traffic--." The dual nature of the DCS in supporting both command and control and administrative traffic is well established. However, the use of the term essential in JCS guidance as applied to administrative traffic is ambiguous and subject to different interpretations on the part of the user and the communications communities.

- Current policy guidance addresses facsimile as a single entity without recognizing that the impact of facsimile on a particular subsystem of the DCS must be evaluated separately for each major category of facsimile application.

- Current policy guidance as reflected in the GAO facsimile report [7] "encourages strongly the use of common-user or shared facsimile equipment, if appropriate." Although this policy is based on sound economic advice, discussions with MILDEP communicators indicate that it is being interpreted too stringently in some areas, thereby denying a major benefit to the user of convenience facsimile service for by-passing on base distribution delays where these delays contribute significantly to reducing mission responsiveness.

- The large majority of potential facsimile users in the convenience categories probably have little or no interest in communicating with the tactical community. Accordingly, compliance with tactical specifications for all equipments procured places an undue constraint on the cost-conscious, low-volume or non-tactically oriented user.

- There currently is no capability within AUTOVON to determine whether a call in progress is a facsimile transmission. Accordingly, compliance with any policy concerning frequency of usage via AUTOVON will have to be on the "honor" system until such a capability can be developed and implemented.

c. Facsimile Service From the User's Point of View. The means by which a user can acquire facsimile service in the DoD in any particular case, depends in part on the user's perception of the relative merits of each alternative - which may or may not coincide with that of the communicator. The following four factors, listed in descending order of importance, appear to guide the user's choice:

Ease of obtaining service

User Cost

Service Reliability

Security

Each of these factors is discussed in the following sections.

(1) Ease of Obtaining Service. Use of AUTOVON during the "busy hour" is discouraged, although use during the non-duty hours is encouraged in JCS guidance. Little effort on the part of the user is needed to acquire service unless new access lines are required.

Facsimile applications over AUTODIN are being encouraged; however, access requires expensive, special equipment and specific operating procedures which may or may not be acceptable to a given user.

Commercial service in the form of the public dial network is readily accessible to the DoD user who is authorized to place "authorized-official" long distance calls. For larger traffic requirements, commercial leasing, primarily in the U.S., may be authorized when volume or other technical considerations render a leased service more cost-effective than the Government switched networks or public dial service. However, as discussed earlier in this report, there is increasing indication that lease service is being authorized in some cases due either to false economy (to preclude DCS backbone charges) or to a lack of responsiveness to user needs on the part of the communications community.

For secure voice application, service is restricted to those requirements that have received approval from proper authority in accordance with JCS guidance, and that utilize equipment approved by NSA. Approval is currently difficult to obtain due to the limited trunking available for secure voice. This situation will improve with future implementations, but will likely be limited to those facsimile applications which are in direct support of secure voice conversations.

Dedicated point-to-point DCS circuitry is available primarily at Government-owned overseas locations, and, due to the limited assets available, is approved only for those facsimile applications that are essential to the mission objectives of the military forces and cannot be satisfied within the current switched networks. As the switched networks are enhanced to support general facsimile operation, justifying dedicated facsimile service will become even more difficult.

(2) User Costs. Due to the specialized nature of the applications justifying commercial lease or dedicated DCS circuitry, the cost aspects of these applications are not addressed in this report. The remaining service alternatives are compared with each other in the following discussion, first for the case of desk top FAX, and then for centralized convenience/mailroom FAX applications. Both cases are viewed from the perspective of the Government as well as the user, since these cost perspectives may be significantly different for many applications.

(a) Desk Top FAX. A cost comparison between AUTOVON and the dial-up public network for desk top FAX applications is given in Figure 15 from the viewpoint of the user and in Figure 16 from the viewpoint of actual costs to the government. AUTODIN without a dial-up A/D conversion capability is not considered a viable alternative for this application.

These comparisons assume that the user already has access to AUTOVON and are based on six minutes per page operation, although 4-minute service is also currently available at reduced resolution (64 LPI). The specific calculations and assumptions made in constructing Figures 15 and 16 are given in Appendix E.

Average utilization for desk top applications is expected to vary from 1 to 10 pages per day, with an average of 3 (including a header sheet). It can be seen that as volume increases the user perceives no increase in AUTOVON costs but a large increase in commercial cost. With higher utilization rates and "long haul" calling patterns, the differences will tend to influence the user in favor of AUTOVON for long distance transactions where this service is available and the frequency of preemption can be tolerated.

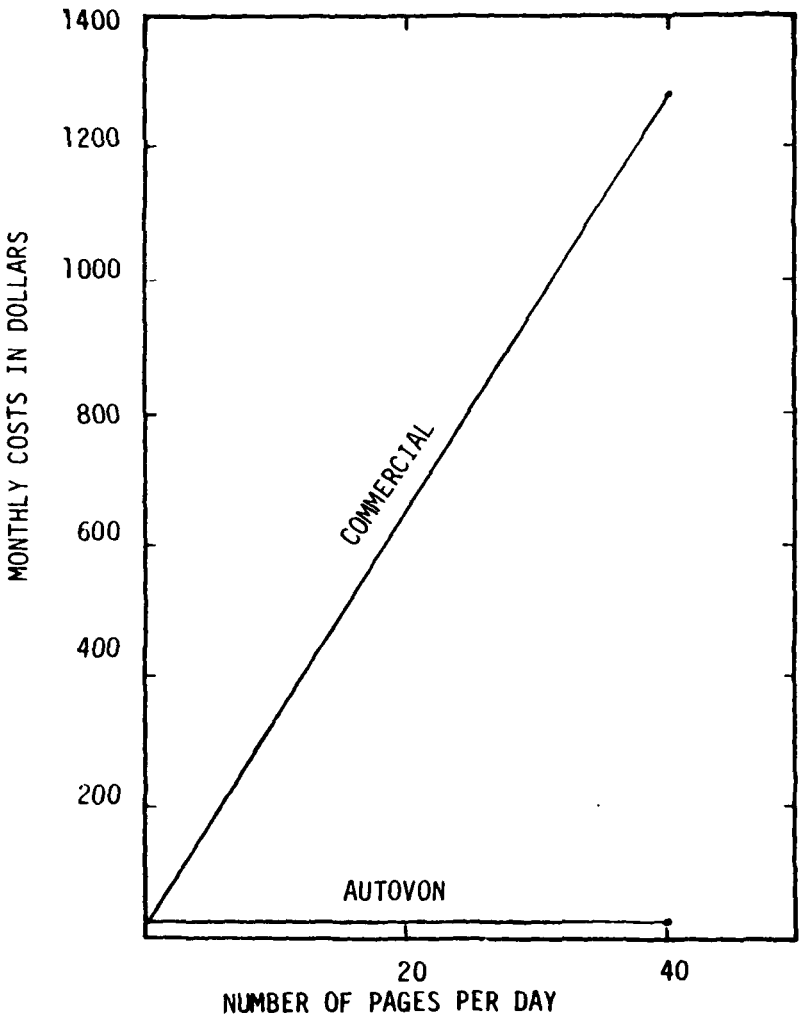


Figure 15. Desk Top FAX - User Costs

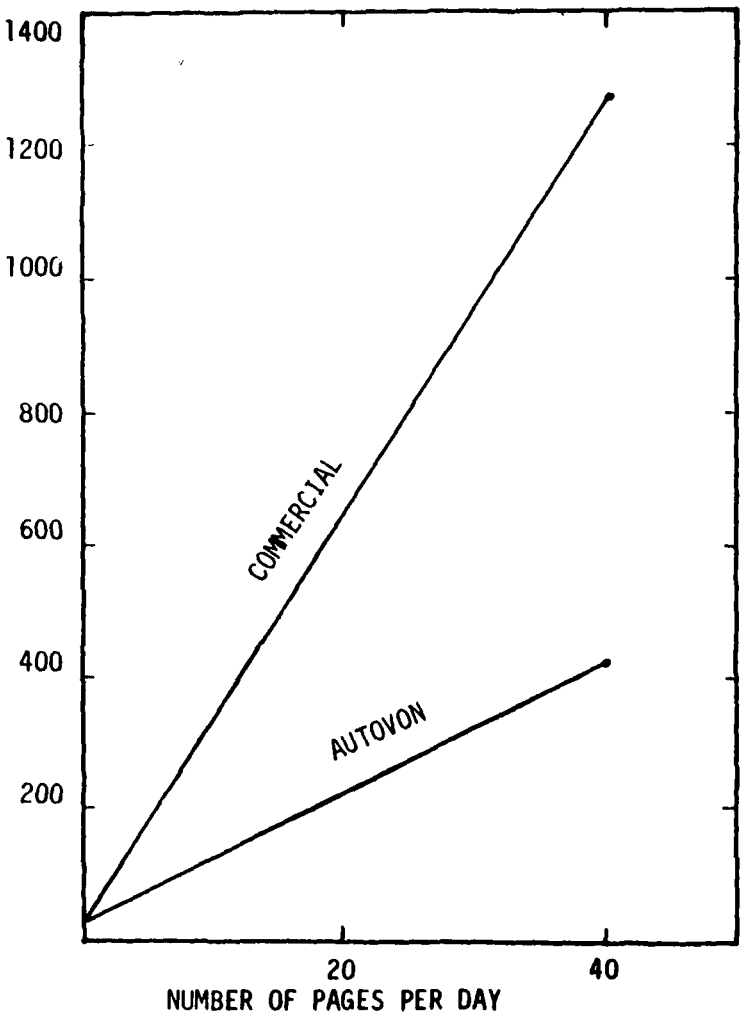


Figure 16. Desk Top FAX - Government Costs

(b) Centralized Convenience and Mailroom FAX (Non-Secure operation). Cost comparisons between AUTOVON, AUTODIN, and the public dial-up network for non-secure centralized convenience and mailroom FAX applications are depicted in Figure 17 from the user's point of view and in Figure 18 from the government's point of view. The calculations and assumptions associated with each of these figures are provided in Appendix E. The following considerations apply to the development of the curves:

- No value is associated with the use of Pacific AUTODIN from the viewpoint of the government, since the Pacific AUTODIN is currently considered to be underutilized and can absorb a significant increase in traffic volume without additional assets, as discussed in subsection 3 - AUTODIN. This may not be the case, however, for the European and CONUS AUTODIN, which are currently considered to be more heavily loaded.

- A separate alternative labeled "VON Piggy Back" has been included for those applications where AUTOVON service is currently available and an additional access line is not required. An additional cost of $.11 per page transmitted is added, however, to reflect the fact that additional access lines will be required to maintain current grade of service as volume grows.

- Applications are initially expected to vary from 2 to 30 for the centralized convenience applications and from 10 to over 200 for the mailroom application, and then increase as facsimile becomes an established telecommunications service within DoD.

(c) Centralized Convenience and Mailroom FAX (Secure Operation). The case for the secure mailroom application is very similiar to the non-secure case, as shown in Figure 19 which depicts user costs and in Figure 20 which depicts actual costs to the Government. Calculations supporting these figures are given in Appendix E. Again, the user views AUTODIN costs as prohibitive, when in fact the costs are much closer than for the non-secure case due to the need to use digital FAX equipment for each alternative. The cost of crypto and its auxiliary equipment is not included for ease of computation, but would be the same irrespective of application. The effect of data compression, available now to all three alternatives, is reflected in the reduced transmission costs and results in AUTOVON service over existing access circuitry again being the least costly alternative for lower volume (less than 35 pages per day) application.

The data used in the cost evaluation is presented for the "average" case only and is sensitive to the values assumed for the cost of a typical commercial call, the time value of AUTOVON usage, the mix between local and long distance traffic, and the actual compression ratios achieved. However, the main point is that the user perceives DCS switched services, and in particular AUTODIN, as much more expensive than the actual cost to the government due to current backbone pricing strategies.

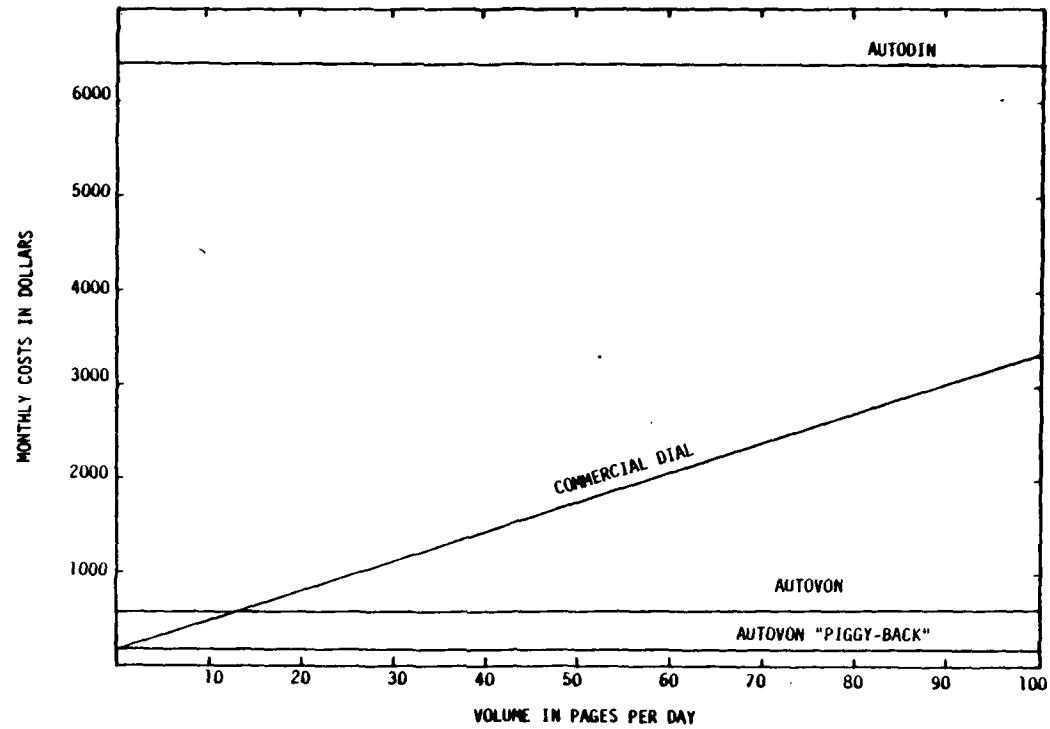


Figure 17. Mailroom/Centralized Convenience Non-Secure FAX Operation - User Costs

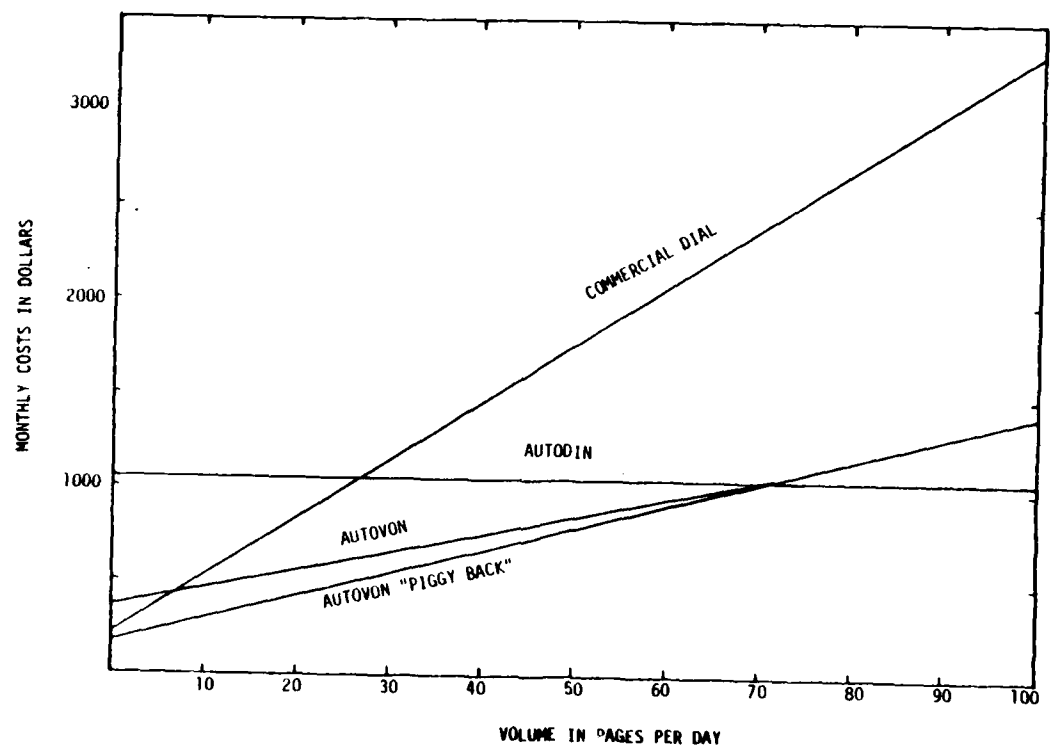


Figure 18. Mailroom/Centralized Convenience Non-Secure FAX Operation - Government Costs

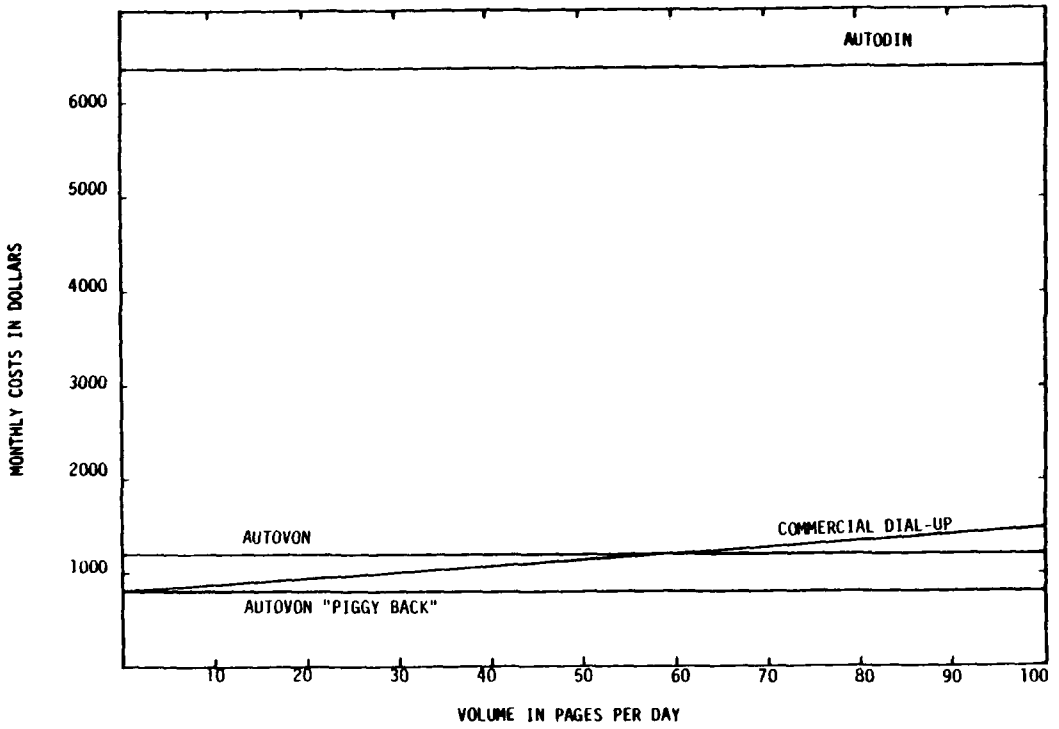


Figure 19. Mailroom/Centralized Convenience Secure FAX Operation - User Costs

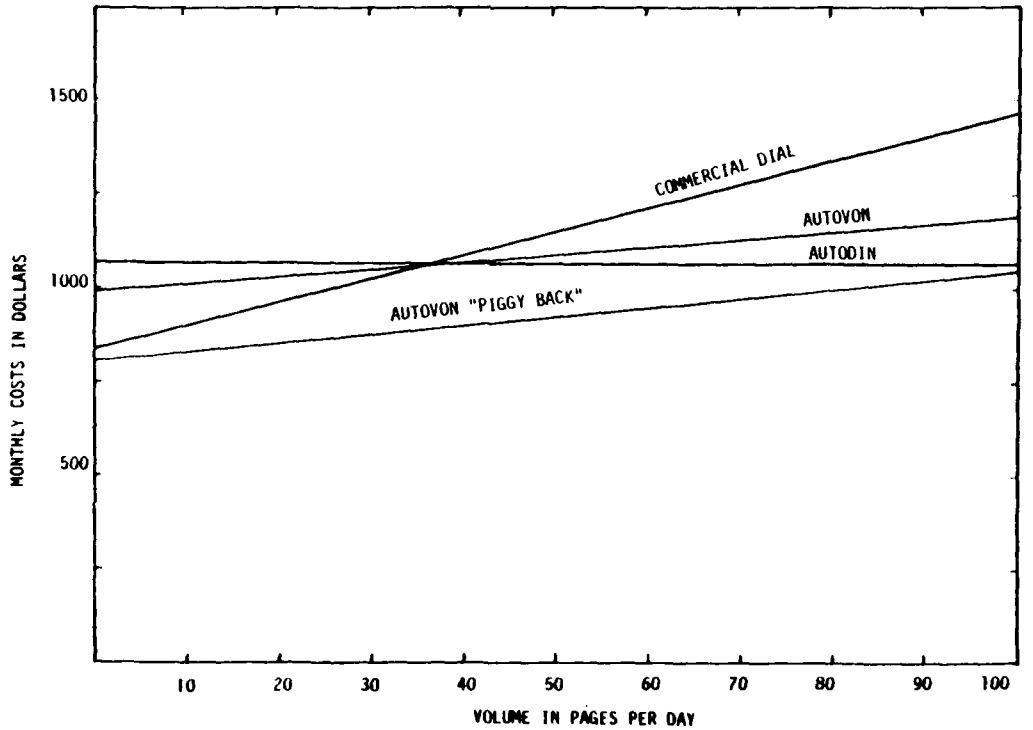


Figure 20. Mailroom/Centralized Convenience Secure FAX Operation - Government Costs

The following points should also be made in regard to the difference in cost perspective between user and communicator.

- AUTOVON is cheaper than commercial dial-up service at all utilization rates.
- AUTODIN becomes more cost-effective than either commercial dial-up service or AUTOVON within the range of volume expected for the average mailroom operation.
- AUTOVON is the least-cost alternative for low volume convenience facsimile operation. However, operation should be restricted to the non-busy hour periods to preclude adverse impact to the voice users of the network.
- AUTOVON as a cost effective solution for low volume applications is hampered by the abnormally long holding times characteristic of facsimile transmissions and the lack of a traffic billing capability which can recognize this and ensure that the facsimile user pays his fair share of network costs.

(3) Service Reliability. The main drawback to the use of AUTOVON in lieu of AUTODIN or commercial dial-up service for convenience facsimile, is the preemptive nature of the network. The problem may not be as serious for certain applications as first thought, but for others the need for uninterrupted service effectively rules out AUTOVON except possibly for after duty hours operation.

For mailroom applications, where volumes are higher and the inefficiencies caused by retransmission less acceptable, difficulty in the use of AUTOVON is encountered much faster. This problem could be relieved to a considerable extent by utilizing the "store-and-forward" features of the typical mailroom analog equipment (automatic load and transmit) in an attended or unattended, off-duty hour operation when the impact on both the network and the user would be much less severe.

The unattended solution via AUTOVON will be acceptable to the user only if a very high probability of non-preemptive service can be given for non-duty hour transmission, because of the impact of a single preemption on the automatic operation of an unattended facsimile terminal.

(4) Security. Secure facsimile operation can be provided either over AUTOVON or AUTODIN using TEMPEST approved digital facsimile equipment. Operation over the secure voice network via acoustic coupled analog terminals is also feasible at low utilization rates. However, most of the current analog equipment is of a design which will not meet TEMPEST approval because of the use of an electric arc in the recording process. Accordingly, secure operation in a convenience application is not considered economically feasible at this time because of the costs of equipment and facilities required.

2. AUTOVON

a. Introduction. The analysis evaluating the impact of facsimile on AUTOVON, is conducted separately for the inter and intra area networks due to differing trunking constraints. In addition, the analysis is viewed from two separate vantage points: the impact which increasing facsimile demand may have on AUTOVON voice grade of service, and the impact that current AUTOVON constraints and design concepts may have on the needs of the analog facsimile user.

There are currently 75 AUTOVON Switching Centers worldwide; 60 in CONUS, five in the Pacific, and 10 in Europe. Studies have recently been completed which recommend the phasing out of six switching centers in the CONUS network. Studies are in progress to review the trunking configuration within the Pacific and Europe and between the overseas areas and CONUS. However, since these studies were neither finalized nor approved when the analysis for this report was made, the current network configuration is assumed for the purpose of this report.

b. Network Impact. There are three primary considerations in evaluating the impact of facsimile demand on the existing AUTOVON network: network traffic handling capacity at the routine level, the costs of additional interswitch trunks to support added traffic demand, and the effect which facsimile traffic above ROUTINE precedence might have on priority and above voice Grade of Service (GOS). These factors have a considerably different perspective depending on whether the analysis is conducted for the busy hour or for the off-duty hour periods.

(1) Busy-Hour Analysis. The expected impact of increasing routine busy-hour facsimile demand on AUTOVON is given in Figures 21 through 26 for the Pacific, Europe, and CONUS respectively. Inter-area facsimile transmission was not addressed because busy-hour routine AUTOVON service between CONUS and the overseas areas is impractical with current inter-area trunking assets.

The top set of curves for each area addresses the effect of increasing busy-hour demand on the overall Grade of Service (GOS) in the existing network for a combination of analog desk top and mailroom facsimile. The bottom set of curves for each area shows the cost of expanding the existing network to maintain the current grade of service as the demand for analog facsimile increases. The following additional comments apply to Figures 21 through 26:

- The cross-hatched area on each figure represents the range in expected demand for 1981, as previously discussed. The boundaries of the cross-hatched area are found by taking boundary values for DoD's share of the facsimile market, as projected in section III, and multiplying by the most likely value for the total market in the target year.

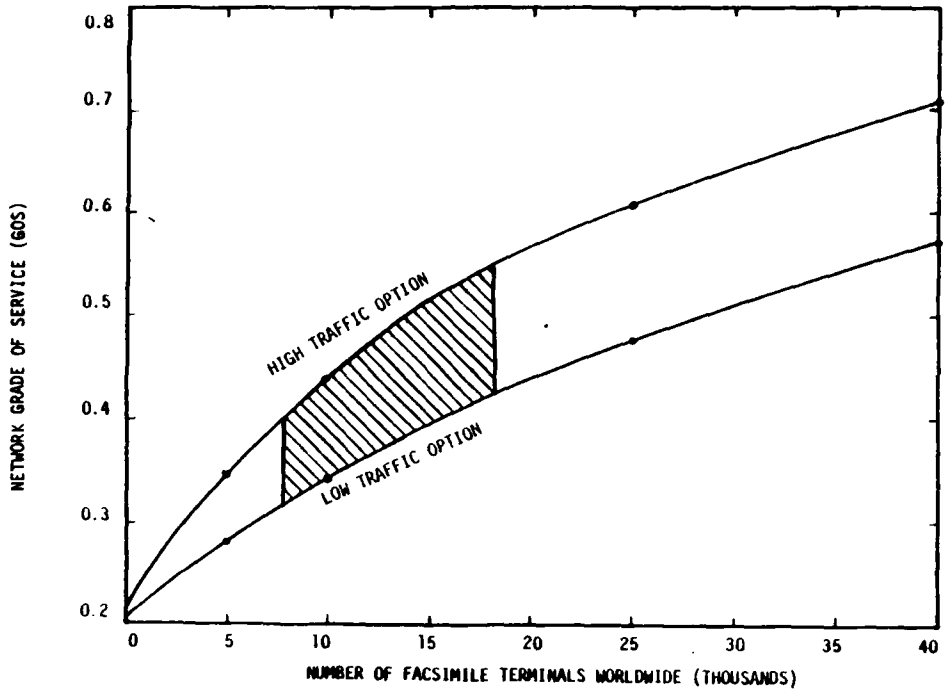


Figure 21. Intra-Pacific AUTOVON GOS for Increasing Facsimile Demand

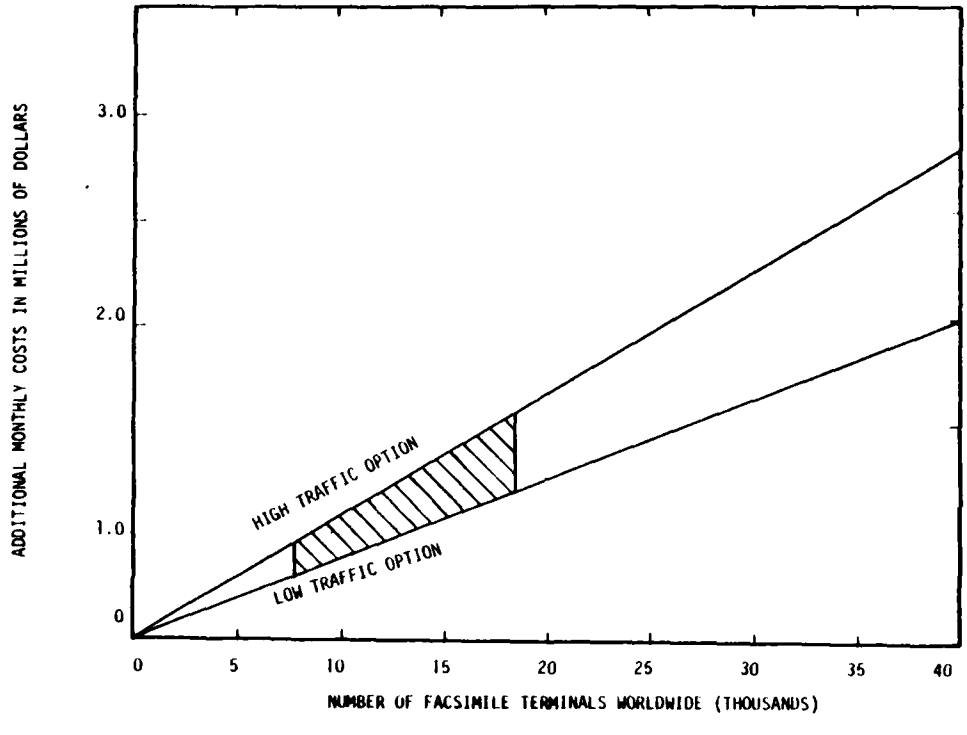


Figure 22. Additional Costs to Maintain Present Intra-Pacific GOS with Increasing Facsimile Demand

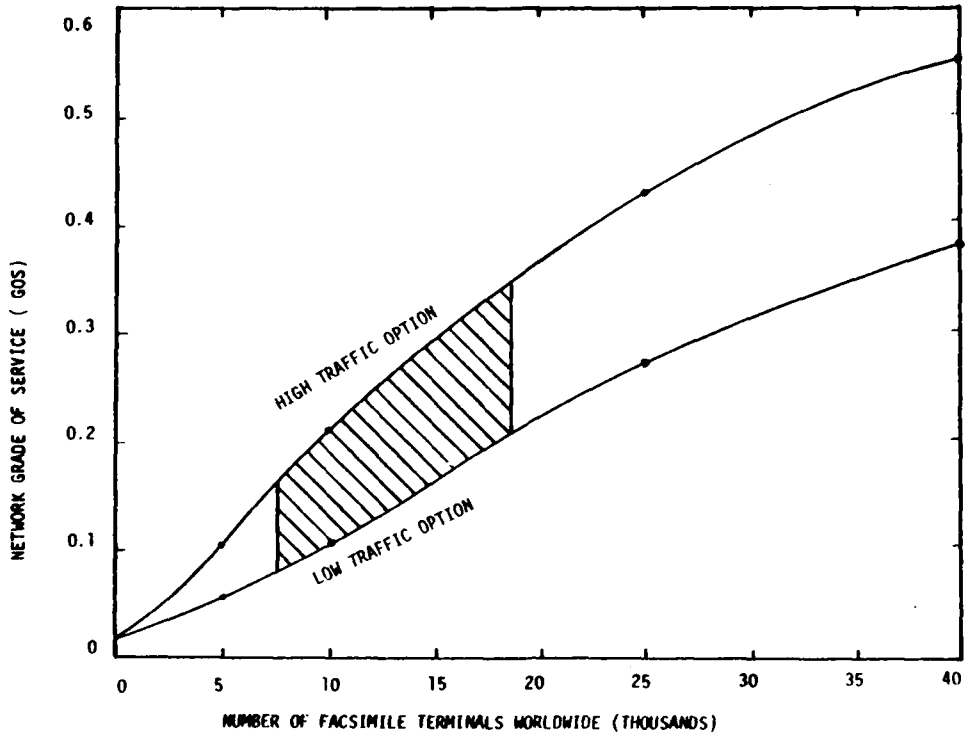


Figure 23. Intra-Europe AUTOVON GOS for Increasing Facsimile Demand

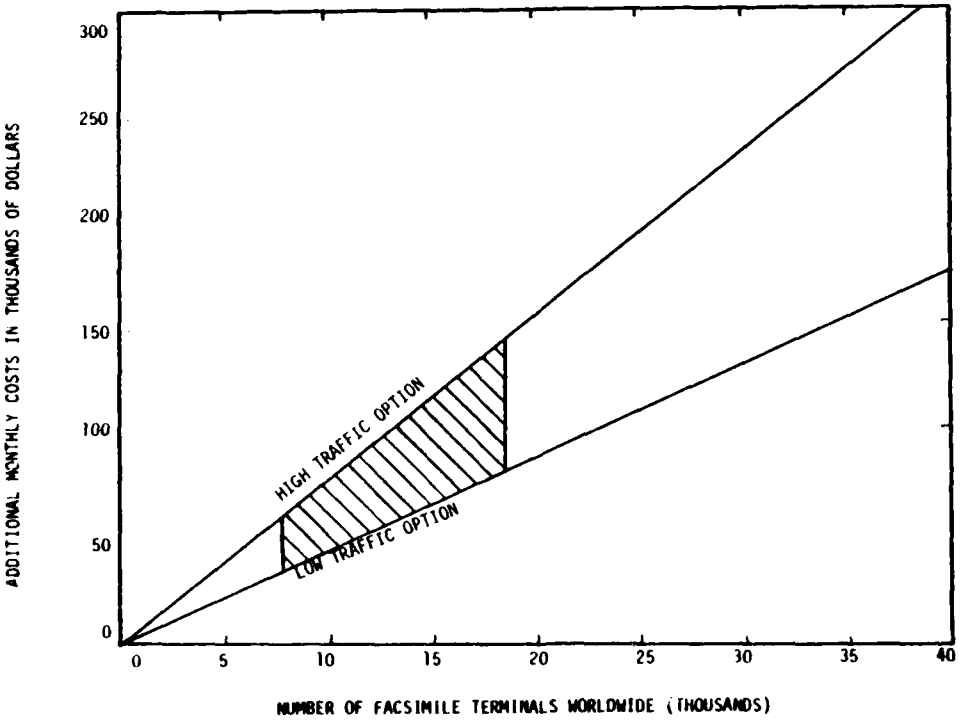


Figure 24. Additional Costs to Maintain Present Intra-Europe GOS With Increasing Facsimile Demand

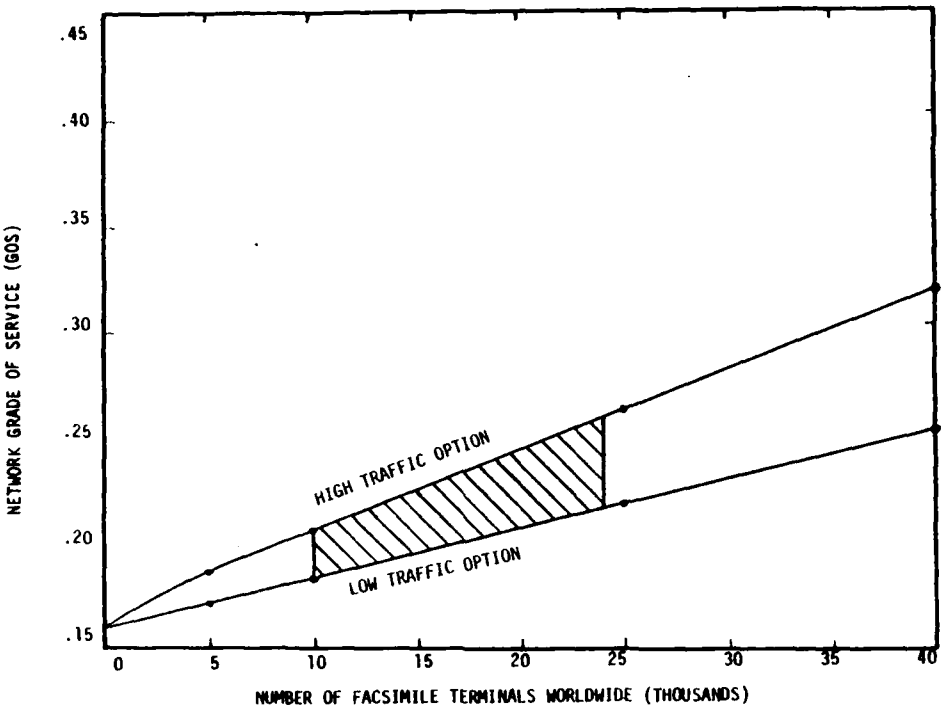


Figure 25. Intra-CONUS AUTOVON GOS for Increasing Facsimile Demand

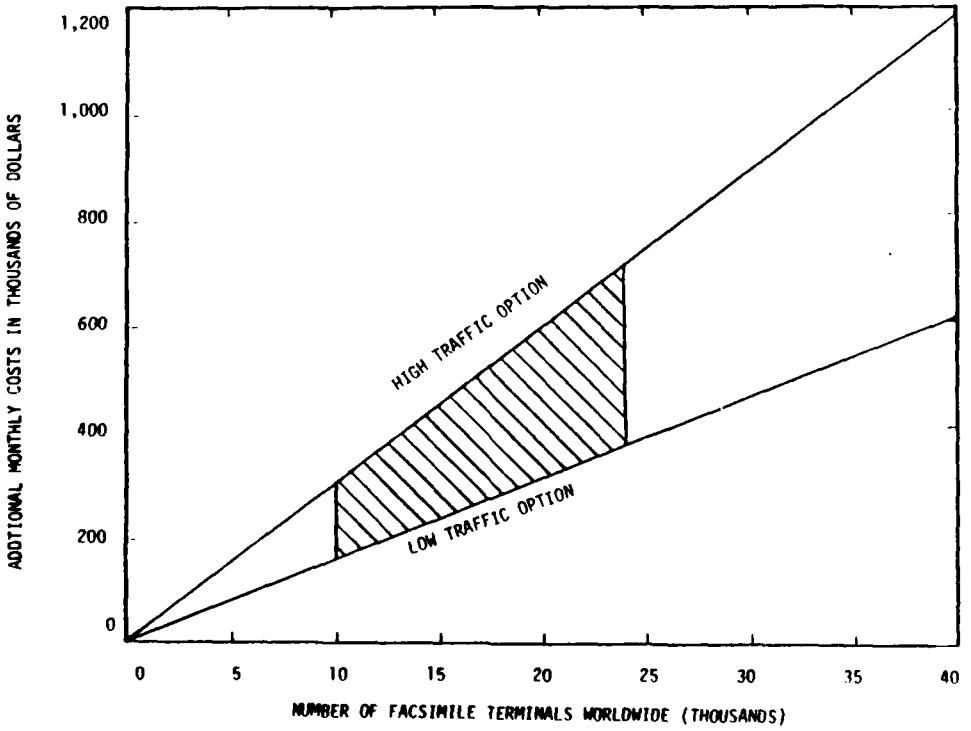


Figure 26. Additional Costs to Maintain Present CONUS GOS With Increasing Facsimile Demand

- High and low traffic options are assumed which are considered to be reasonable boundaries to what will most likely occur over the next three to five years. The method used in deriving these boundary values is given in Appendix E.

- All facsimile traffic has been considered to be ROUTINE due to limitations in the network model at the time these calculations were made. Some precedence traffic, however, is expected as a part of future facsimile demand. Should the amount become excessive, the voice GOS depicted in the figures could deteriorate even more rapidly than shown.

- The relative distribution of mailroom FAX applications between AUTOVON and AUTODIN I has not yet been determined. For the preliminary evaluation, this distribution is arbitrarily assumed to be fifty-fifty.

- The growth of facsimile within the overseas area will probably fall behind that of CONUS by 1 to 2 years.

- A busy hour model is used with a uniform distribution of desk top traffic over a 6 hour day and of mailroom traffic over a 10 hour day. With the availability of inexpensive terminal equipment having programmable calling and automatic transmission capability, increasing demand may spread more to the non-busy periods and not reflect a proportional increase in busy hour traffic as has been assumed for this study.

The additional trunk assets required to maintain current voice grade of service could possibly be justified for low volume convenience applications, through cost avoidance by using AUTOVON instead of more costly alternatives. A sample cost curve for CONUS demonstrating the economics of this point is given in Figure 27. This figure shows the percentage of total convenience FAX terminals required to use AUTOVON to completely finance the increased trunking necessary to support all projected convenience facsimile needs. This figure is based on the cost differential between AUTOVON and commercial service as given in Figure 18 for non-secure FAX operation, and the increased costs to maintain current grade of service in the CONUS network as shown in Figure 26 for both the high and low traffic options.

The use of AUTOVON for higher volume mailroom or comm center operation during the normal duty hours is not considered to be a feasible alternative to AUTODIN in view of the considerable impact which increasing facsimile traffic could have on the voice users of the network. However, application of relatively inexpensive ($3500) store and forward facsimile compression equipment, such as the FAX-COMP produced by Compression Labs, Inc., in conjunction with the analog facsimile terminal or as a dial-up service, could significantly reduce the impact which convenience and lower volume mailroom operations would have if used over AUTOVON. In effect, a six minute per page analog facsimile terminal could transmit continuously for one hour into a FAX-COMP or similar device;

be compressed and stored on a floppy disk; and then outputed through the network to a similar device at the receiver location in a burst of less than 5 minutes duration. This technique of facsimile transmission has the added advantage that it is not significantly affected by preemption since the device can automatically re-initiate the call and begin transmission at the point of interruption.

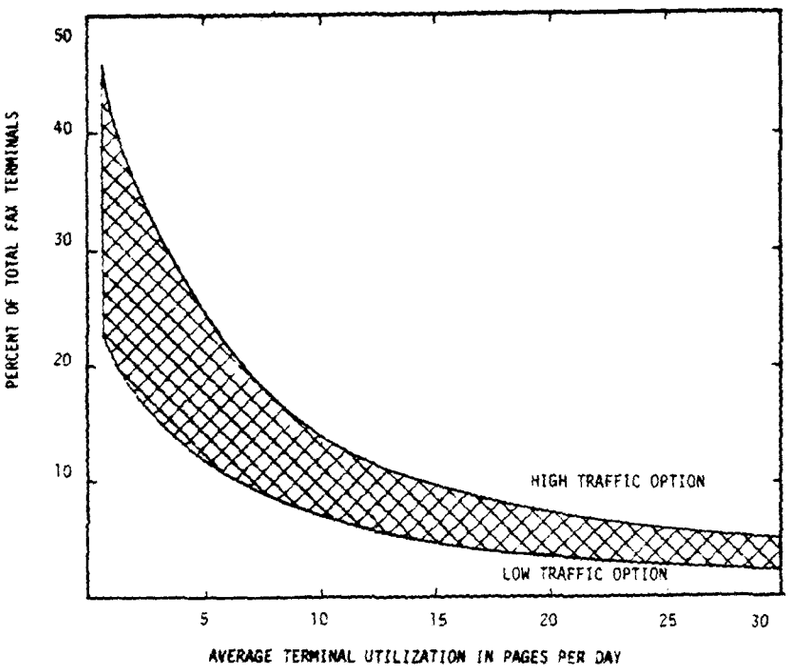


Figure 27. Cost Avoidance Example for AUTOVON vs Commercial FAX Service at Different Utilization Rates in CONUS

(2) After-Hours Analysis. The excess AUTOVON capacity available for facsimile service in the Pacific and Europe, and between these areas and CONUS, during the off-hours is depicted in Figures 28 and 29. These figures reflect a P.03 GOS and are based on a twenty-four hour traffic estimate, developed by DCA Code 520 from data obtained from the Traffic Data Collection System (TDCS) for Europe and the Pacific. Similar data requested from AT&T for CONUS could not be provided due to problems encountered by AT&T in processing the off-hour traffic data collected from the CONUS AUTOVON switches. However, an AT&T AUTOVON traffic engineer familiar with the CONUS AUTOVON configuration, estimated the excess off-hour capacity for facsimile service in CONUS to be approximately 3,000 erlangs for the period between 1700 and 0600 hours EST.

The current European AUTOVON configuration, incorporating the switch at Donnersberg, Germany as a fourth gateway to CONUS, was used in the analysis. The configuration used for the Pacific AUTOVON assumes satellite load control,

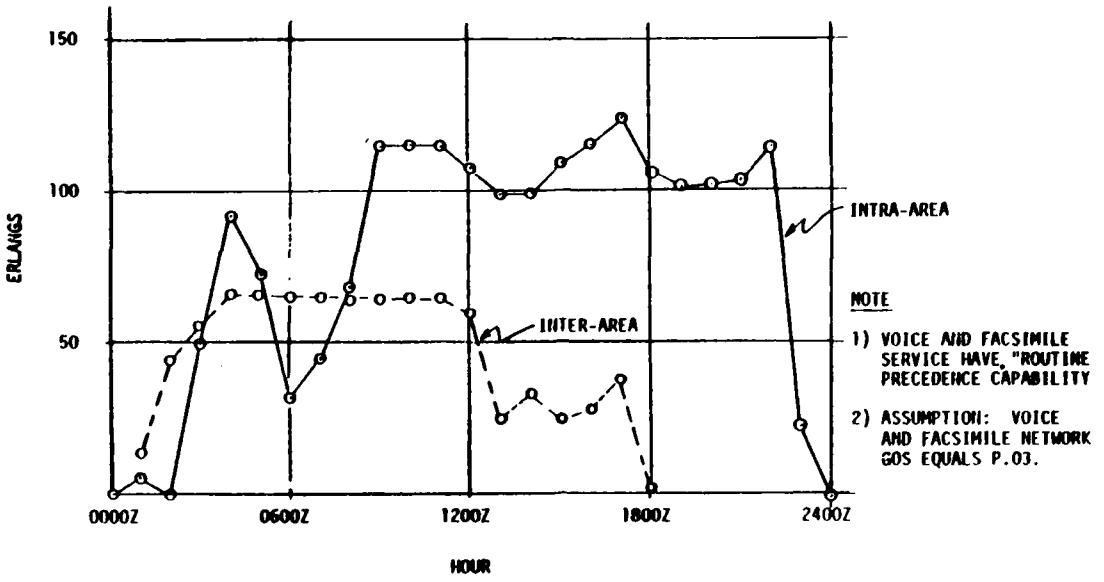


Figure 28. Excess Pacific AUTOVON Capacity Available for Facsimile Service

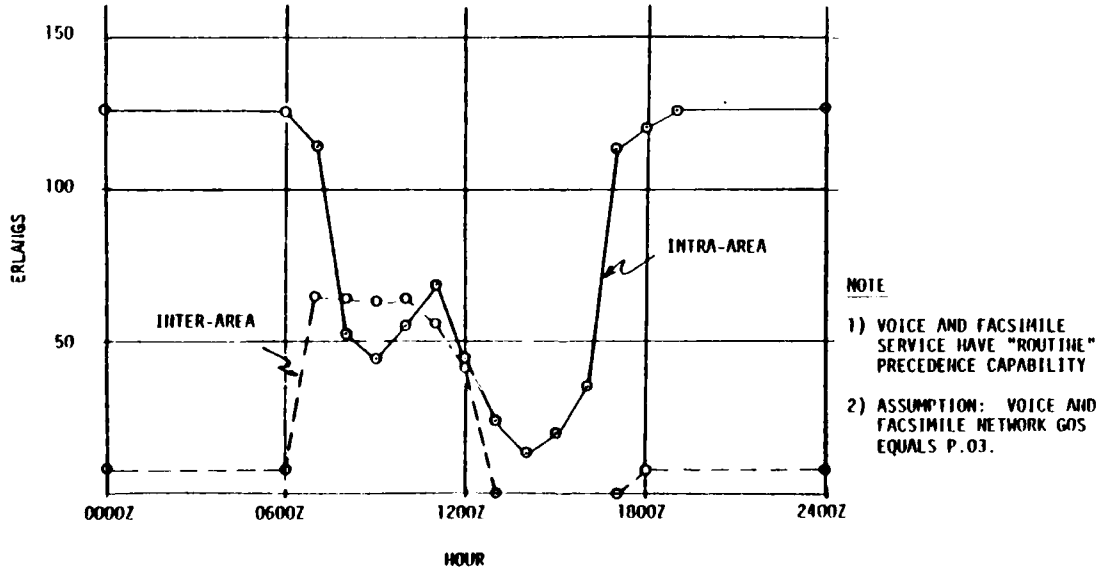


Figure 29. Excess European AUTOVON Capacity Available for Facsimile Service

tentatively scheduled for implementation in 1981, and the switch at Fort Buckner, Okinawa as a fourth gateway to CONUS. Additional assumptions assumed in the off-hours analysis are given in Appendix E.

It can be seen from these figures that a considerable capacity for off-hour facsimile operation exists in the current AUTOVON network.

c. User Impact. The DCEC computer models and analytic techniques used for the busy-hour analysis required modification to evaluate the impact of network constraints and design concepts on the needs of the user. These modifications have just been completed and have been used for the off-hours analysis only. The impact of the busy-hour configuration on the needs of the user was conducted without the use of the revised model and utilizes a simulation model developed for the Pacific area only.

(1) Busy-Hour Analysis. Figures 30 and 31 show the results of the simulation on the low traffic desk-top FAX application. Similiar data for the high option and for mailroom operation were not obtained due to the amount of computer resource required for the simulation. Figure 30 depicts the decreasing probablity of a typical ROUTINE facsimile user being able to complete an average (three page) transaction as the demand for facsimile in the Pacific increases.

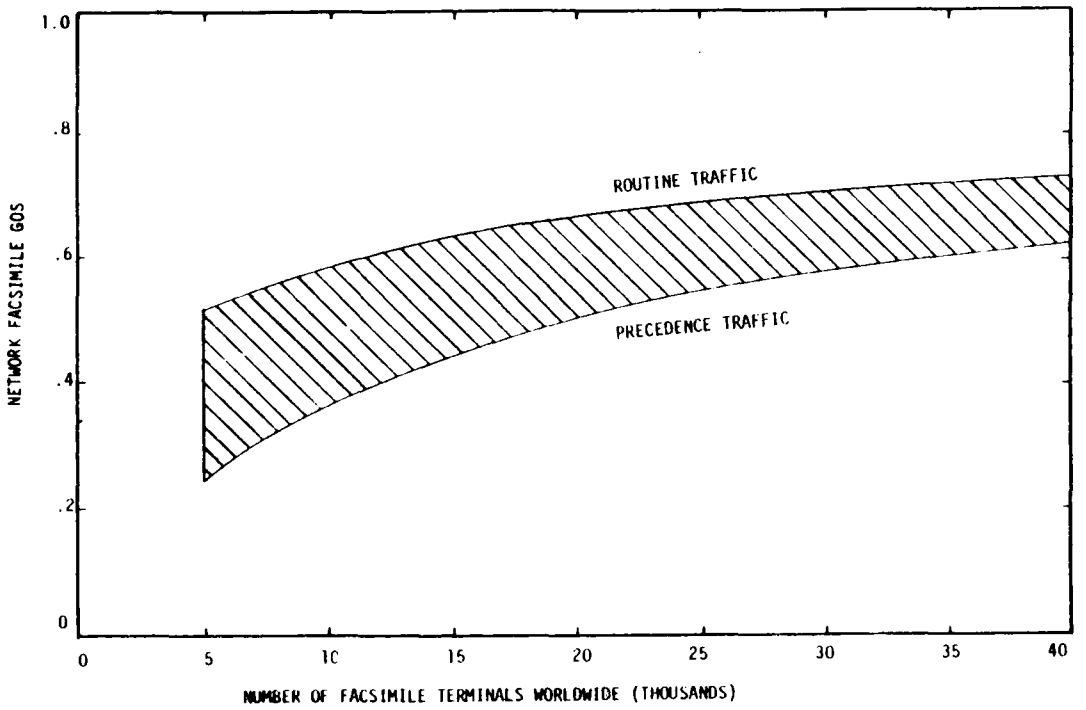


Figure 30. Total GOS for Facsimile Users With Increasing Demand - Pacific Area

The effects of increasing facsimile demand on voice GOS are shown in Figure 31. It can be seen from these figures that facsimile service to the ROUTINE FAX user in the Pacific area will not be satisfactory within the confines of the current network.

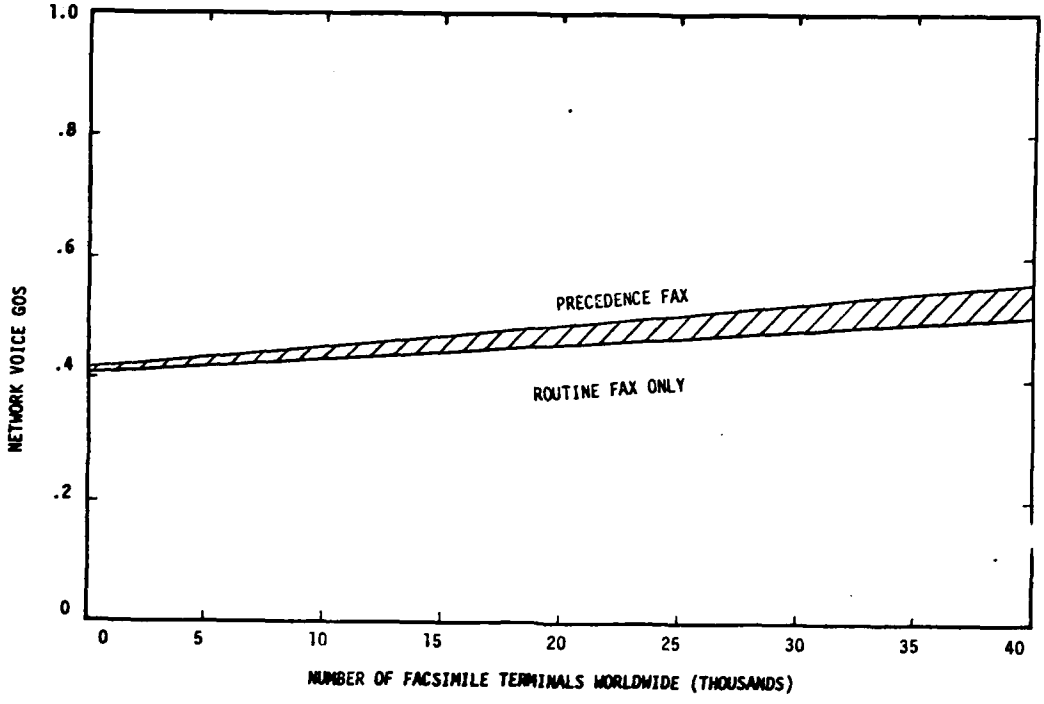


Figure 31. Change in Voice Grade of Service With Increasing Facsimile Demand - Pacific Area

The simulation model also provided insight into the relative utilization of each trunk group, and thus indicated which can be expected to cause the major constraints to traffic growth. The results of this portion of the evaluation, given in Appendix E, indicate that the trunk groups between Wahiawa and Japan and between Wahiawa and CONUS will likely be the first major bottlenecks to facsimile traffic growth.

(2) Off-Hours Analysis. The performance of the Pacific and European AUTOVON for off-hour intra-area facsimile service is shown in Figures 32 and 33. These figures give the probablity of unpreempted facsimile service and network voice GOS as a function of offered traffic. The assumptions made in constructing these figures are the same as previously discussed under network impact.

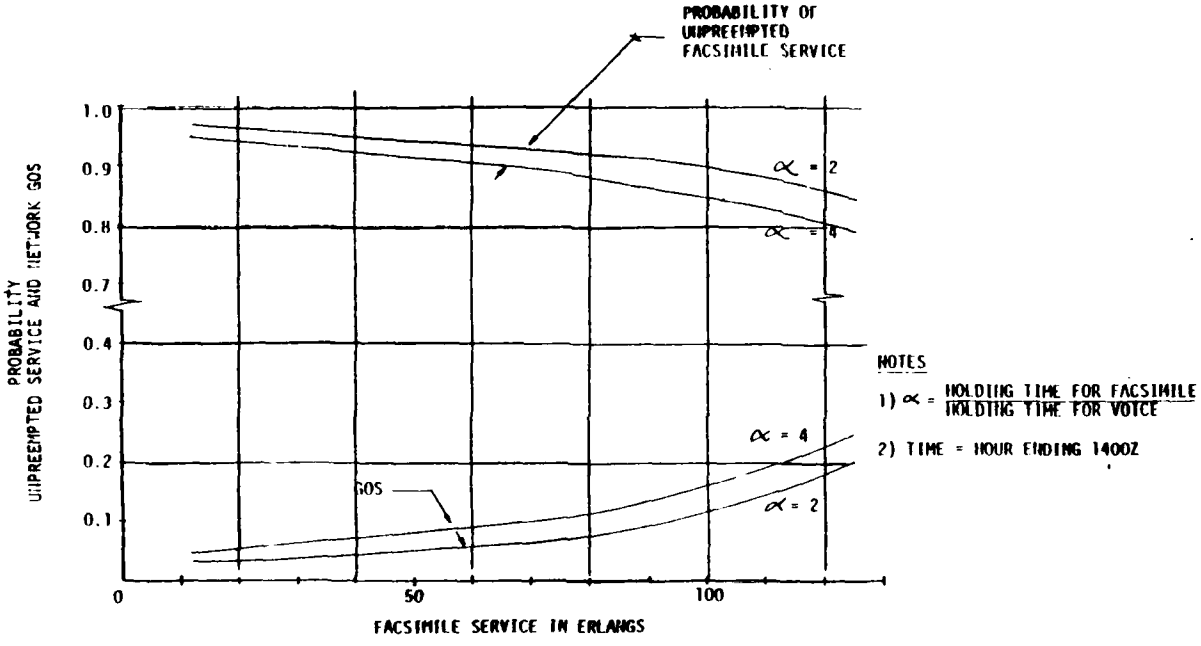


Figure 32. Performance of Pacific AUTOVON for Off-Hour Routine Intra-Area Facsimile Service

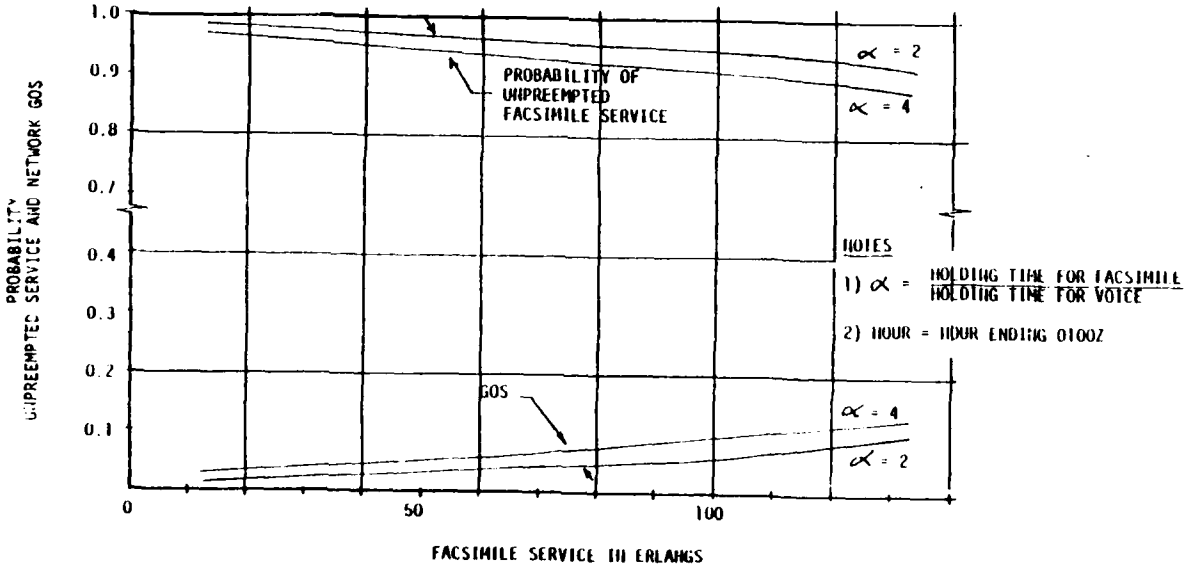


Figure 33. Performance of the European AUTOVON for Off-Hour Routine Intra-Area Facsimile Service

Figures 34 and 35 give the same information for inter-area service. The slightly degraded performance of the inter-area network compared to the intra-area network is due primarily to: the reduced network capacity between the overseas areas and CONUS, and to the fact that inter-area traffic which originates from non-gateway switches will also compete with intra-area traffic. In neither case, however, should off-hours facsimile traffic originated in the appropriate time slot be significantly affected by preemption unless unattended operation without call reestablishment capability is utilized. Similarily, off-hours facsimile traffic should not have any major impact on voice grade of service unless a major increase in facsimile demand is experienced.

d. Summary. The analysis of AUTOVON leads to the following conclusions concerning the impact of facsimile:

- Analog facsimile transmission between CONUS and the overseas areas during normal duty hours is not currently feasible at ROUTINE precedence because of the limited circuit assets between these areas.

- Busy-hour AUTOVON operation in the Pacific is the worst case for analog facsimile traffic, both in terms of the effect of increasing demand for facsimile on the voice GOS, and the cost to maintain that GOS by increasing trunking assets. The primary traffic bottlenecks appear to be the trunk group capacities between Hawaii-Japan and Hawaii-CONUS.

- Europe appears to be the most capable of accepting duty-hour analog facsimile traffic, but will degrade much faster than will CONUS with increasing demand.

- The application of low-cost store and forward facsimile compression equipment (such as the FAX-COMP), either at the user's location or at the network interface, could significantly reduce the impact of analog facsimile operation over the "duty hour" AUTOVON.

- Both the intra-area and inter-area networks appear to have considerable potential for accepting off-hours facsimile traffic, especially during certain time slots. However, this would require unattended operation or an over-the-counter service not requiring the after-hours presence of the user and safeguards to insure that utilization does not spill over into the normal duty hours if this solution is to have major effect.

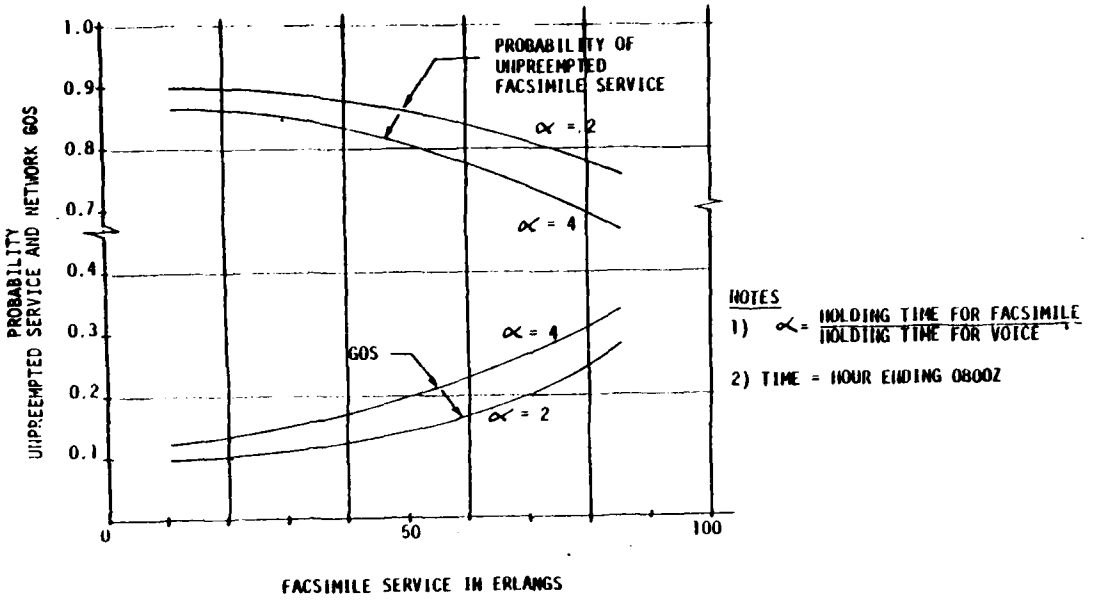


Figure 34. Performance of Pacific AUTOVON for Off-Hour Routine Inter-Area Facsimile Service

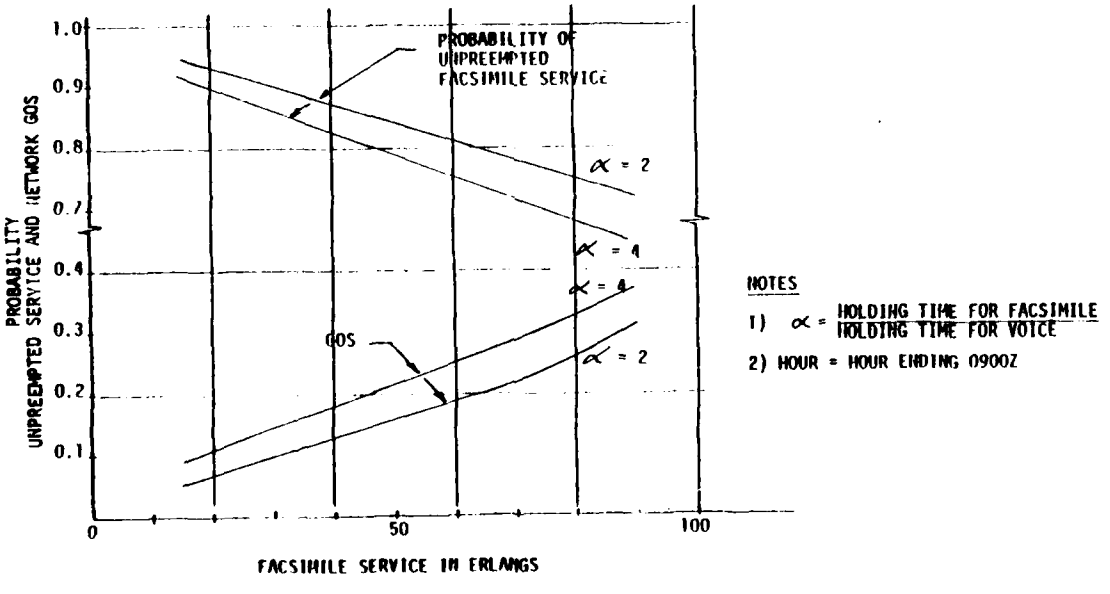


Figure 35. Performance of the European AUTOVON for Off-Hour Routine Inter-Area Facsimile Service

3. AUTODIN

a. Introduction. In evaluating the potential impact of facsimile on AUTODIN, the analysis again is divided into three separate areas - the PACIFIC, EUROPE, and CONUS - to reflect differing access line, interswitch trunk, and ASC operating costs. Due to other priority projects, only a "desk top" evaluation of one area could be undertaken at this time. The Pacific was chosen because it is the easiest to model and thus can provide insight for evaluating the other areas.

There are currently five Automatic Switching Centers (ASC's) in the Pacific, interconnected with 11 interswitch trunks including those to CONUS. The switch at Wahiawa is leased, while the rest are Government-owned. Plans are currently underway to close the ASC at Clark and, since these plans are approved, this ASC is assumed closed for this report. The resulting configuration is as shown in Figure 36.

b. Network Impact. There are three primary constraints in evaluating the impact of facsimile demand on the AUTODIN network: switch termination capacity, network traffic handling capacity, and the costs of additional interswitch trunks to support the added traffic demand. No distinction is made between busy-hour and off-duty hour operation due to the store and forward nature of AUTODIN.

(1) Switch Terminations. Table XI summarizes the number of switch terminations currently in use and the maximum available for the Pacific. It can be seen that since 63 percent of current capacity is available for additional terminal and interswitch trunk connections, switch termination capacity poses no serious barrier to the growth of facsimile in the Pacific.

TABLE XI. SUBSCRIBER TERMINATIONS PACIFIC AREA

ASC	NUMBER OF TERMINATIONS IN USE	NUMBER OF TERMINATIONS AVAILABLE
GUAM	36	100
DRAKE	54	150
TAEGU	61	100
HAWAII	71	250*
TOTAL	222	600**

*Subject to increasing ADU memory from 6 to 8 Banks.
**Upon closure of Clark ASC

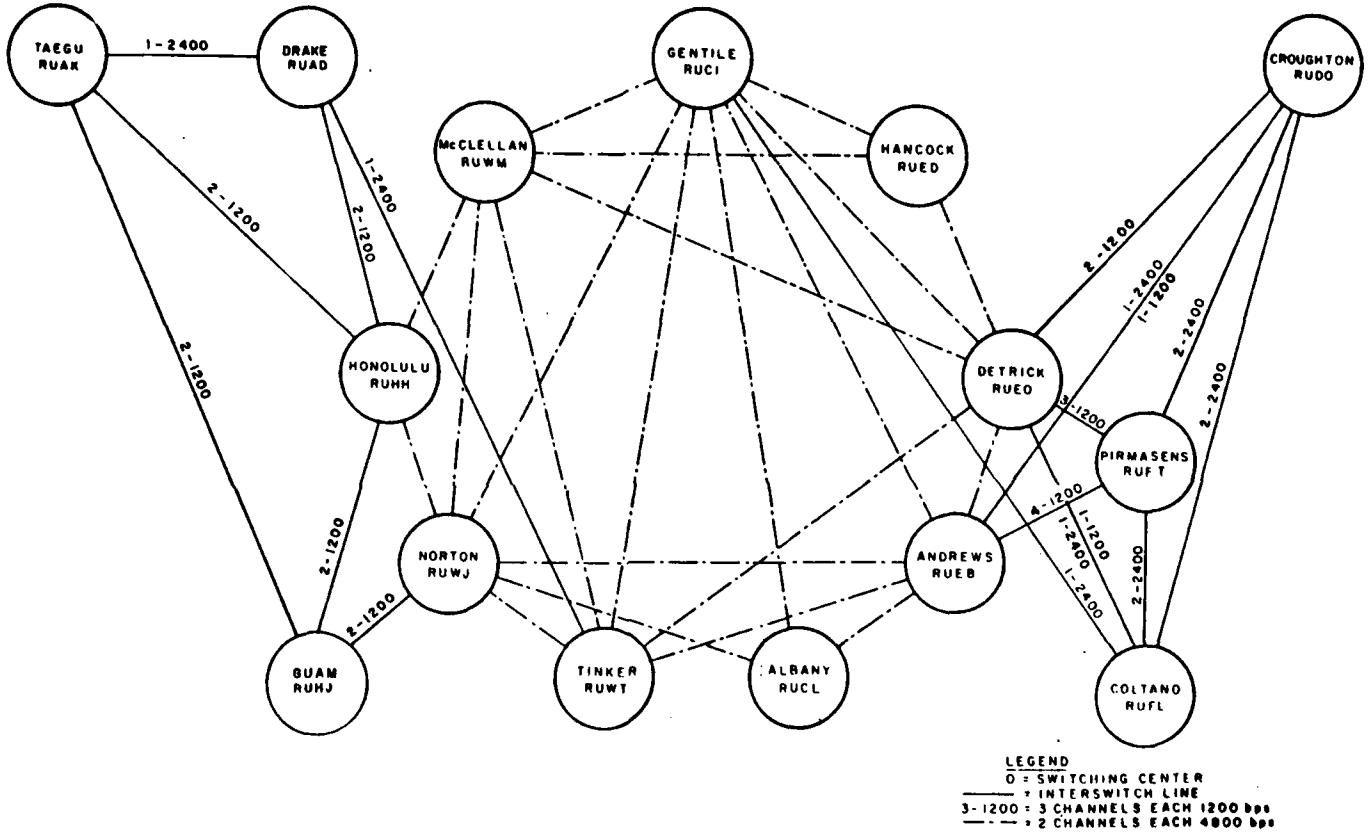


Figure 36. Worldwide AUTODIN Configuration

(2) Network Traffic Handling Capacity. Network traffic handling capacity, as a constraint to facsimile growth, is more difficult to evaluate because switch throughput capacity must first be determined and then added to the effects of the interswitch trunk configuration. The evaluation of switch throughput capacity is complicated by the complex interactions between traffic flow, processing overhead, and cycle time for various mixes of high and low speed terminations and traffic categories. Such studies have been performed in the past. However, the results are now over 8 years old and can be considered only as approximate in view of the many changes incorporated in the software since that time. For the purpose of this report, individuals familiar with these studies and subsequent software modifications have been asked to estimate a current value for switch throughput capacity. The values obtained are 200 ±50 line blocks per second (lb/s) for leased ASC's and 175 ±25 lb/s for the Government-owned ASC's. Using these values to represent ASC throughput capacities and including the network considerations described below, a value of 151 lb/sec for the Pacific network was derived as the threshold below which there is a high confidence that network traffic handling capacity will not constrain traffic growth. This value is based on the following considerations:

- Facsimile traffic was assumed to be geographically distributed within the Pacific in the same proportion as current AUTODIN I narrative traffic.

- The load on the individual trunks of the network was evaluated from two aspects. First, many of the messages from the Pacific to CONUS leave during the non-busy period and, therefore, do not contribute to the need to resize the CONUS trunks. The reverse is also true for a large proportion of the CONUS traffic destined for the Pacific. Second, from an examination of the current SNAPS traffic reports, Table XII, it was found that 27 percent of the messages originated in the Pacific are destined for subscribers of the same ASC, 67 percent are destined for subscribers one trunk path away, and 6 percent for subscribers two or more trunk paths distant.

- Network traffic handling capacity was found to be very sensitive to the average number of addresses per originated "message"-2.6 for narrative AUTODIN traffic, and 1.9 as a network average. Accordingly, the initial computed value of 173 lb/s as a threshold for the Pacific network traffic handling capacity was changed to 151 lb/s as a "best guess" of the effect of multiple addressing on facsimile traffic (assumed to average less than half the value for narrative AUTODIN traffic, but taken as 1.5 as a worst case estimate).

TABLE XII. TRAFFIC DISTRIBUTION BETWEEN ASCs

FROM	TO:	RUAD	RUAK	RUAO	RUCI	RUCL	RUDO	RUEB	RUED	RUEO	RUFL	RUFT	RUHH	RUHJ	RUMM	RUWJ	RUWM	RUWT
RUAD	1	3879	502	0	83	110	61	874	635	1962	18	16	1917	239	522	308	277	364
	2	648	184	0	34	30	22	287	310	810	4	4	371	66	142	78	148	97
RUAK	1	492	3045	0	68	103	5	209	252	450	10	11	540	23	188	144	107	288
	2	158	1569	0	25	16	1	44	48	268	5	3	151	4	54	60	42	154
RUAO	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
RUCI	1	463	298	0	6416	3809	528	1672	2295	1979	937	748	433	154	225	3248	1623	2991
	2	132	71	0	2586	1112	103	656	752	1026	194	317	142	28	43	1973	520	1052
RUCL	1	376	254	0	2985	10205	1073	5355	2462	3699	1652	1260	481	305	345	3851	814	2863
	2	94	64	0	1779	3823	378	2610	1111	1593	451	406	134	87	94	1446	254	1153
RUDO	1	82	6	0	397	542	6501	3928	227	980	1482	2321	57	87	63	243	171	481
	2	39	1	0	171	158	1285	1039	68	306	417	696	20	31	30	104	54	122
RUEB	1	863	510	0	1661	3917	3127	9311	1957	3505	1233	1425	841	373	462	2088	1973	2161
	2	309	168	0	1231	1495	973	2726	977	1647	363	399	344	107	139	712	771	806
RUED	1	313	260	0	1371	2444	594	1711	5685	2336	855	683	515	160	285	1931	2156	2492
	2	72	103	0	827	968	165	983	3885	1354	191	475	113	29	51	1753	781	1085
RUEO	1	1940	1083	0	3191	7135	3388	4495	3097	16300	3911	3519	1794	424	1016	3205	4266	3868
	2	641	481	0	1356	2680	1106	1359	1930	6419	1234	1540	639	105	348	1539	1426	1381
RUFL	1	39	11	0	467	451	1593	790	349	2635	6806	2632	29	8	34	343	204	562
	2	16	4	0	250	120	524	188	109	762	1430	1118	11	2	11	237	97	151
RUFT	1	29	23	0	544	818	2255	2820	371	1389	3450	9428	54	18	11	303	190	778
	2	7	6	0	359	175	678	719	147	379	1212	2199	18	5	3	155	89	207
RUHH	1	2022	611	0	326	763	126	1156	1227	1660	338	108	4054	1186	1986	1821	2690	586
	2	1053	179	0	88	231	45	316	243	382	164	42	913	324	554	519	607	180
RUHJ	1	508	138	0	115	197	84	484	221	382	81	50	853	1895	527	478	411	229
	2	151	59	0	98	66	28	116	104	97	32	20	174	297	151	164	131	67
RUMM	1	454	261	0	103	227	185	278	345	791	8	24	854	1235	2399	307	160	272
	2	150	82	0	59	84	82	107	161	303	2	7	245	249	399	126	44	68
RUWJ	1	994	308	0	1632	2574	263	2777	2660	2439	405	530	1820	2025	825	9383	2196	2105
	2	275	130	0	677	710	70	1172	2608	880	111	380	342	575	257	4217	946	840
RUWM	1	517	243	0	1139	1076	204	1217	1751	2204	346	322	1287	430	407	2567	8546	2210
	2	144	81	0	334	300	39	235	829	879	52	72	192	85	91	904	2157	854
RUWT	1	685	431	0	3563	3014	980	3015	2235	3213	1256	1683	676	351	420	2615	2729	10804
	2	154	91	0	1937	1387	233	960	1291	1678	314	550	160	79	107	1178	954	4367

LEGEND:
1. MESSAGES
2. LINE BLOCKS (EXPRESSED IN HUNDREDS)

(3) Cost of Trunk Assets. Figure 37 depicts the cost of increased trunking necessary to maintain current network speed of service for increasing facsimile demand. This curve was developed from the following considerations:

- The determination of what average trunk utilization value should be used to insure acceptable network operation is based on the "rule of thumb" that if the mean trunk utilization in the Pacific is 50 percent, individual trunks will be approaching the point where additional capacity on that trunk path is required.

- The interswitch trunks in the Pacific area use a mix of media and multiplexing schemes to derive the individual circuits. One of the trunks is Government-owned while the remainder are leased for a total cost of $80,472 per month. Accordingly, the average cost of additional trunking is taken to be $10,059 per trunk with the assumption that additional GFE trunks will not be available.

- An examination of the traffic for several sample days indicates that the average 2400 b/s trunk in the Pacific is utilized 26 percent of the time during the 6 hour busy period. Since the design threshold for increasing trunk capacity is a utilization factor of 50 percent, a significant amount of increased facsimile traffic (24 lb/s) can be absorbed by the network before any additional trunking is required.

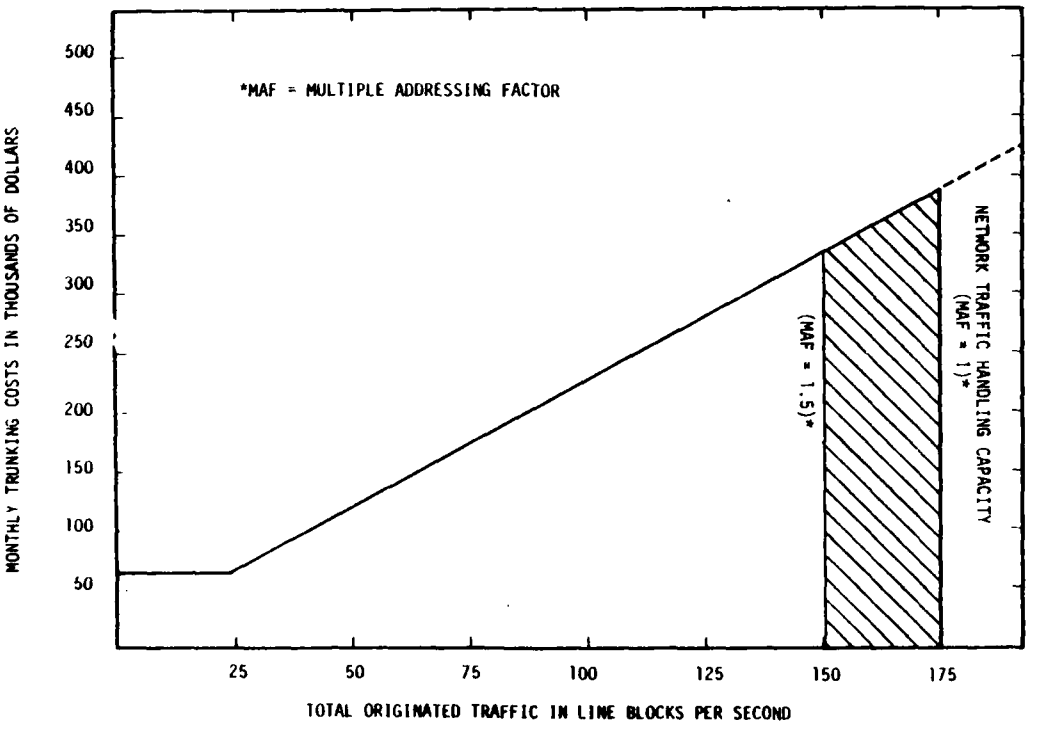


Figure 37. Network Costs Versus Increasing Facsimile Demand - Pacific AUTODIN

Figure 38 depicts the impact of increasing facsimile demand on the Pacific AUTODIN in terms of the number of mailroom facsimile terminals deployed. The growth in demand is shown for "high" and "low" utilization factors. In addition, costs are also given in terms of the percent increase over current network costs to provide a better perspective of the cost situation. The network traffic handling threshold is depicted as a horizontal line at a total increased cost of approximately 415 percent, corresponding to the 151 lb/s vertical line in Figure 37. The switch termination barrier is given as a diagonal line reflecting the maximum increase in the number of terminations utilized for inter switch trunks expected as network traffic grows. Finally, it is assumed that the "working" portion of the curve lies to the left of the 150 terminal mark, since growth in mailroom facsimile terminals is unlikely to exceed the current number of AUTODIN Com Center terminals within the near future. Additional factors considered in developing this graph are given in Appendix E.

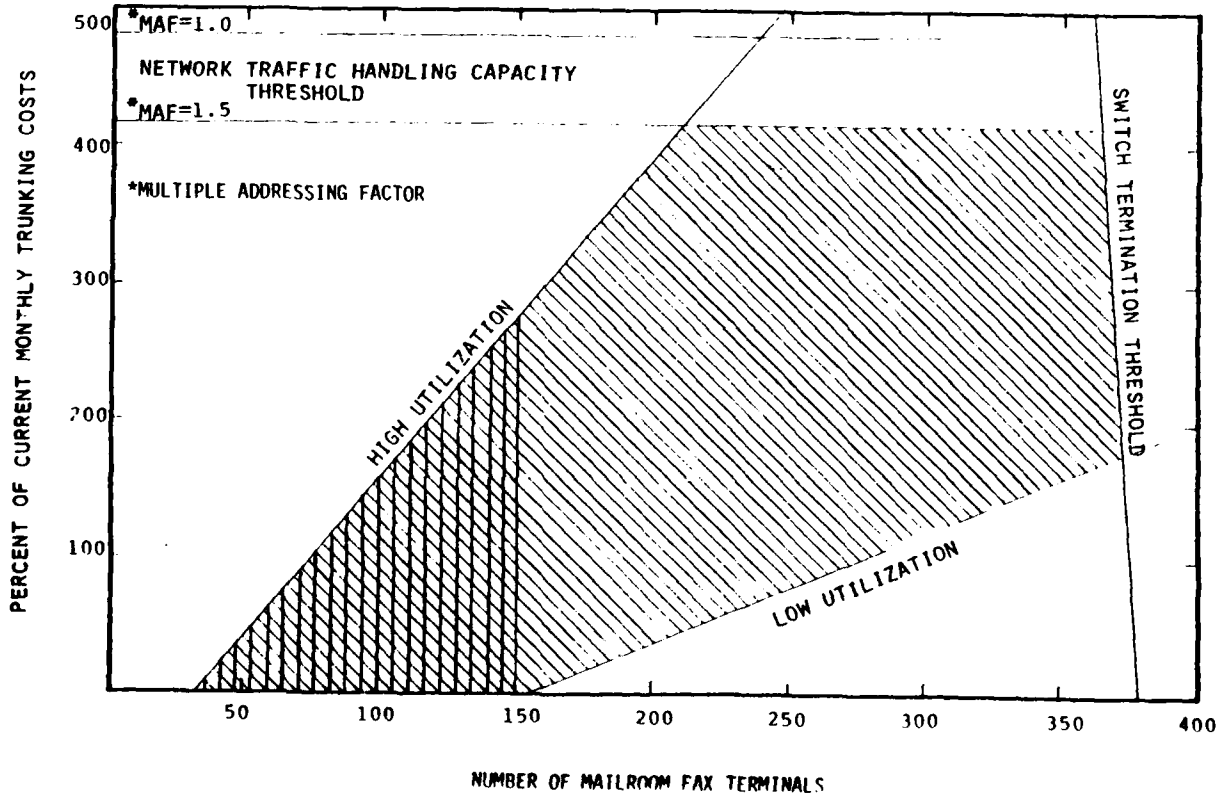


Figure 38. Additional Costs to Maintain Current AUTODIN Speed of Service With Increasing FAX Demand - Pacific AUTODIN (Expected Usage)

c. User Impact. The primary impact of an AUTODIN solution on the user involves the economics of AUTODIN service and the additional hardware required for network protocols. Currently, these considerations limit AUTODIN service to the higher volume centralized communications centers or to applications where security or other considerations override the cost aspects.

In addition, AUTODIN I, with its current input limitation of 4.8 Kbps, is not conducive to the transmission of high resolution photographs requiring a resolution of 400 LPI and 16 shades of gray. Even if input speed is increased to 9.6 Kbps, it would still take over one and one-half hours to input a single photograph with the above specifications.

d. Summary. The anticipated growth of facsimile service does not appear to pose any serious problem for Pacific AUTODIN in the near future (4 to 5 years) unless an additional Pacific ASC is deactivated. Growth beyond this period into a fully implemented electronic mail network, however, will be restricted over AUTODIN I by the need for extremely large bit storage capacities beyond AUTODIN I design limits.

The current PACIFIC network configuration can absorb 33 "high" utilization terminals uniformly distributed, or 155 "low" utilization terminals, or some intermediate mix of the two, without adversely impacting current speed of service. Note, however, that the calculation of network traffic capacity is very sensitive to the multiple address factor (MAF) and distribution of traffic demand.

As the number of facsimile terminals increases beyond 40 to 50,the additional network cost will average approximately $1,600 for each "high" utilization terminal and $300 for each "low" utilization terminal (calculated from the slope of Figure 31). This evaluation has been conducted on the assumption of a 6 hour busy period. Once the current network has reached design limits, shifting facsimile mailroom operations towards the non-busy hour periods is an attractive alternative to increasing network costs but would require increased storage capacity to be effective.

The results of the preliminary effort for the Pacific may not be readily applicable to Europe (with three ASC's) or CONUS (with eight ASC's) where problems are expected due to a considerable difference in the amount of traffic volume per switch, as indicated by figure 39. Accordingly, CONUS and European AUTODIN are expected to have considerably less capacity for facsimile traffic than is the case for the Pacific.

Finally, the ability of AUTODIN I to handle sequential delivery, as required for facsimile transmissions much above 500 line blocks in length, will limit AUTODIN I's effectiveness in meeting any significant increase in non-narrative facsimile traffic demand.

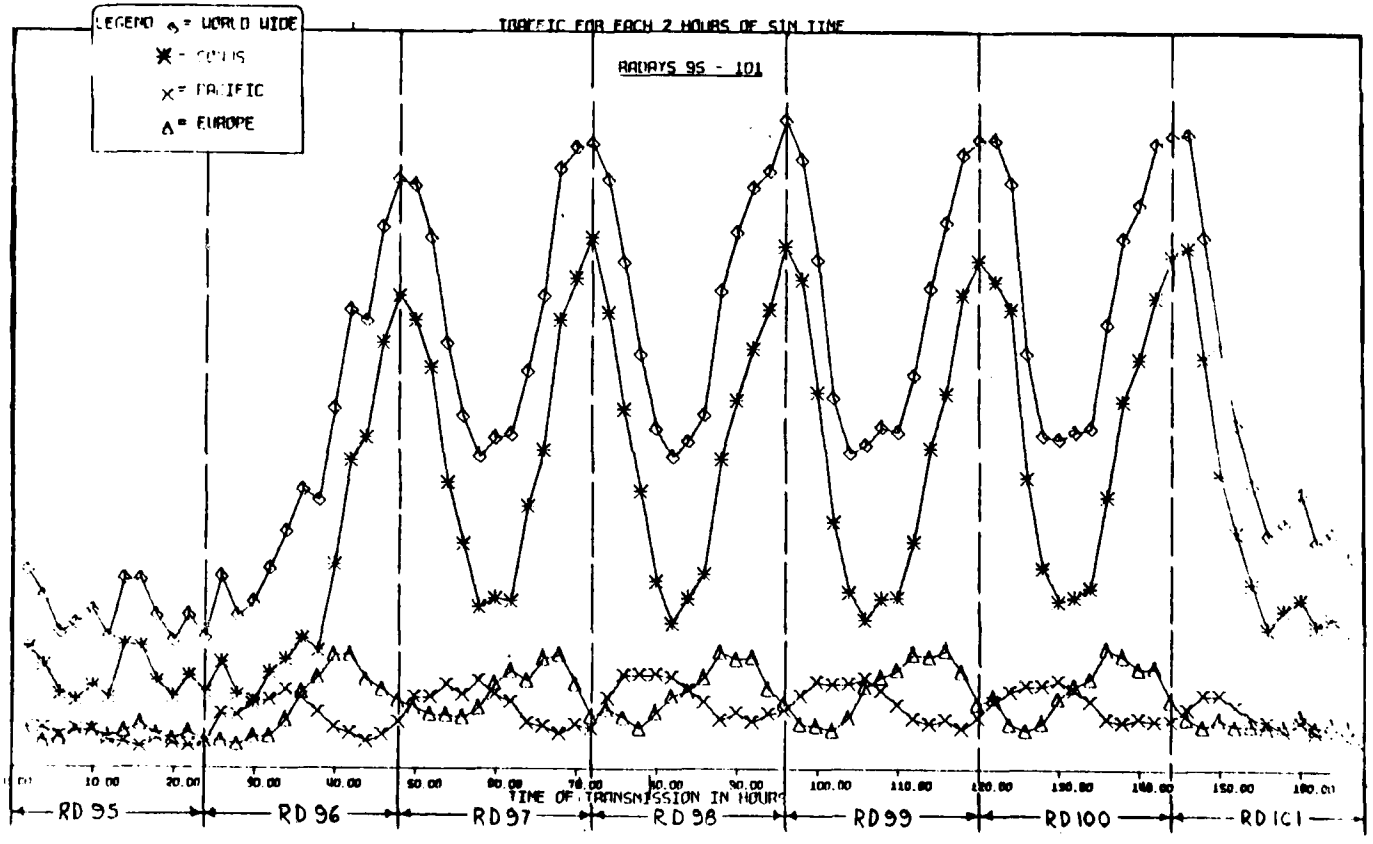


Figure 39 Variation of AUTODIN Traffic, RADAYS 95-101

4. WIDEBAND APPLICATIONS

a. Introduction. The rapid development of lower cost wideband communications services of the type proposed by Satellite Business Systems (SBS) and the Xerox XTEN network are likely to result in the implementation of Wideband Electronic Mail Systems (EMS) much earlier than proposed, even as recent as a year ago. These systems will utilize facsimile equipment that will operate over bandwidths up to 1.5 Mb/s, or higher, and will be capable of transmitting from 360 to in excess of 25,000 pages per hour. At these volumes and data rates, the cost to transmit a single page will be on the order of a few cents.

Facsimile terminal equipment is already available to support wideband operation. Two Japanese manufacturing firms have already produced prototype high resolution facsimile units that can transmit six pages per minute at resolutions of 400 LPI over 56 KHz channels. In addition, AM International has just recently announced a development contract with SBS for supplying prototype electronic mail equipment. Accordingly, the implementation of EMS does not depend upon the development of high speed facsimile equipment but upon the availability of inexpensive communications channels that can support the traffic load at costs users can afford.

The US Postal Service is currently expending considerable time and effort in studying the feasibility of a national electronic mail service. However, the role of USPS in electronic mail is being looked into by the National Telecommunications and Information Administration (NTIA). Based on opinions to date, it is believed by IRD [19] that the USPS will be kept from offering any direct electronic mail service on the grounds that a quasi-public company should not offer services that can be adequately provided by private interprise. The USPS is, therefore, likely to be restricted to offering a mail delivery service only in concert with the electronic carriers.

In DoD, the organizations managing the military mail appear, from informal discussions with their staff people, to be depending on the US Postal Service to investigate electronic mail and have not initiated any programs of their own to investigate the desirability of a DoD electronic mail capability. Since the USPS efforts may come to naught, it would appear that the subject of electronic mail service for DoD needs to be looked at by DCA and the MilDeps.

b. AUTODIN II Impact. AUTODIN II, to be implemented during the early 1980's, will provide a worldwide common-user digital communication service to support automated data processing systems and networks. AUTODIN I is to be retained and integrated into the AUTODIN II network to provide a store-and-forward capability for those users still requiring this service. AUTODIN II is to be a distributed communication network using packet-switching processors. Some of the packet switches will be collocated with existing AUTODIN I switch-

ing centers. Performance requirements of the system are defined in the System Performance Specification for AUTODIN II, Phase I. An initial operational capability consisting of a three-node configuration and a network control center is projected for mid-1980.

The impact which facsimile traffic, and in particular electronic mail application, could have on DCS II, and in particular AUTODIN II, is currently being investigated and the findings will not be available until the conclusion of the follow-on study effort. However, the following appears to be the main areas for concern:

- The efficiency of packet versus circuit switching techniques for large volume (mega-bit) facsimile transmissions.
- The implication of DCS II network design on the terminal options available to facsimile users.
- The expected cost of DCS II service for potential facsimile users.
- The need, either at the subscribers location or within the communications network, for a large buffer/storage capability beyond current design limits to support a fully implemented electronic mail service and the requirements of the intelligence community.

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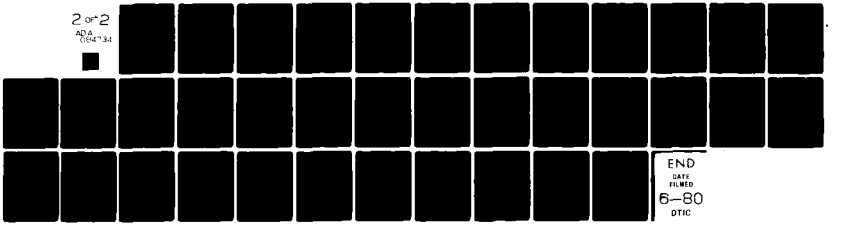

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VI. SIGNIFICANT FINDINGS AND RECOMMENDATIONS

1. SIGNIFICANT FINDINGS

The following major findings relating to DoD facsimile needs and their potential for impacting the DCS were obtained from the study effort:

a. The demand for facsimile service within DoD is increasing at a rapid rate. This increase is expected to be at least 10-fold by 1990, and possibly as high as a 100-fold if the electrical transmission of high resolution photography becomes a major DoD requirement.

b. The impetus for increasing facsimile demand in DoD is largely due to the tremendous growth and decreased cost of facsimile applications in the private sector coupled with the following needs emerging within DoD:

- The desire to by-pass the delays and formalities attendant to current mailroom and Comm Center operations.
- The need for an informal action officer-to-action officer narrative coordination link to enhance the staffing of command actions before official release.
- The need for a "next-day-of-delivery" service that is more responsive than ordinary mail, but not requiring the more stringent delivery time criteria of current AUTODIN.
- The need to reduce the number of specially trained communications personnel.

c. Current policy guidance relative to the implementation of facsimile service within the DCS is based primarily on the traditional precepts of facsimile as a more limited special purpose service and does not fully reflect current needs.

d. Current backbone pricing strategy differs markedly from the true cost to the government of providing that service and therefore does not encourage the user to select the type of communications service that is most cost-effective from the viewpoint of the government, nor to use that service efficiently once obtained.

e. The use of AUTOVON for facsimile service is being discouraged due to the preemptive nature of the network and its heavy traffic load during normal duty hours. The impact of facsimile on the normal duty hours AUTOVON could be significantly lessened by the application of inexpensive store-and-forward facsimile compression equipment, such as the FAX-COMP produced by Compression Labs, Inc.

f. AUTOVON does have a considerable capacity for providing facsimile service in the after duty hours if a store-and-forward capability utilizing unattended terminal operation or network assets can be implemented.

g. The use of AUTODIN for facsimile service is being encouraged. However, the ability of AUTODIN I to handle sequential delivery, as required for facsimile transmissions much above 500 line blocks in length, will limit AUTODIN I's effectiveness in meeting any significant increase in non-narrative facsimile traffic demand. In addition, the high apparent cost of direct AUTODIN service further reduces AUTODIN's desirability for many potential DoD users.

h. DCS II, when implemented, could provide substantial relief to the DoD facsimile problem. However, current design concepts, both for AUTODIN II and the MilDep automated base distribution efforts, will not provide the interface or store-and-forward capacities required for a fully implemented facsimile service.

i. In addition to the limitations cited above, the following situations also provide a limiting influence to achieving the full benefits of DoD facsimile service:

- The various standards programs have tended to resolve the problem of facsimile equipment interoperability completely within the standards arena without fully recognizing the flexibility of current technology for providing "network" solutions.

- The DoD organizations responsible for managing the military mail have no on-going programs to investigate the desirability of electronic mail for DoD application.

j. The future impact of facsimile on the DCS may be reduced somewhat by the following developments projected for the mid-to-late 1980's:

- The improvement in current compression techniques utilized to reduce copy redundancy while minimizing the bad side effects in the area of error control.

- The availability of inexpensive communicating word processing equipment as a more cost-effective alternative to narrative facsimile transmission, and its dissemination throughout DoD.

k. In the interim, current technology and networking concepts are available from at least one manufacturer (Compression Labs) which could combine the best attributes of both AUTOVON and AUTODIN I in providing an effective interim DoD facsimile service, pending the implementation of a fully developed DoD "Electronic Mail" service.

2. RECOMMENDATIONS

The following actions are recommended as initial measures for improving facsimile service in the DCS.

a. Revise current policy directives and pricing strategies to reflect facsimile as a fully mature telecommunications service.

b. Initiate a full study effort, in coordination with the MilDeps, to evaluate the desirability of electronic mail for DoD application.

c. Request that the intelligence community provide DCA a comprehensive assessment of their needs for high resolution facsimile service.

d. Initiate a pilot program utilizing the family of Compression Labs equipment to demonstrate the feasibility of the following facsimile service features:

- An AUTODIN analog-to-compressed digital facsimile conversion capability for low-volume analog dial-in and dial-out facsimile users.
- A store-and-forward automatic dial capability for utilizing the spare after-hours capacity of AUTOVON.
- A network capability for interconnecting digital facsimile users utilizing different data compression coding techniques and signalling protocols.
- A capability to separate facsimile traffic for routing to AUTODIN or to AUTOVON (after-hour service) based on length of transmission or delivery priority.
- A capability for dynamic load allocation between AUTOVON and AUTODIN based on network traffic status.

e. Pending implementation of a fully responsive DCS facsimile service, encourage the MilDep's to procure store-and-forward facsimile compression equipment, such as FAX-COMP, for use with their analog facsimile equipment.

REFERENCES

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APPENDIX A
FACSIMILE COPY QUALITY CRITERIA

1. LEGIBILITY CRITERIA

The legibility of words or characters is the primary factor for establishing the output quality required for "document FAX" applications. In specifying a legibility criteria, a choice is generally made between the following two basic objectives, depending upon whether the application is predominantly text type material or is predominantly graphic material, such as graphs, specifications, numerical data, etc. Figure A-1, taken from Costigan's book [3], illustrates the primary difference between these two objectives:

- Individual letters of a word need not be positively identified so long as the word, as a whole, is legible.
- Identity of the smallest significant individual character must be virtually assured.

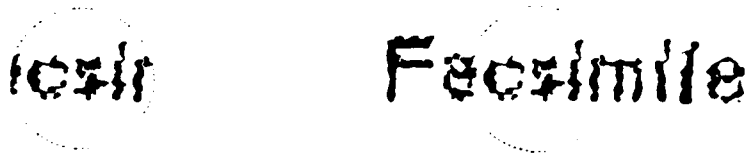

Figure A-1. Individual Character vs Word Legibility

There are various criteria which can be used to specify these objectives depending on the particular application of interest. Table A-I gives the minimum number of scan lines by which an individual character should be dissected to meet objectives 1 and 2 for document type material.

TABLE A-I. MINIMUM NUMBER OF SCAN LINES REQUIRED TO MEET OBJECTIVES 1 and 2 FOR TEXT MATERIAL

Minimum Character Height (inch)	*Approximately Equivalent Type Face*	*Minumum Scan Lines Per Inch (LPI)*	
		1. Identify Words	*2. Identify Individual Characters*
3/64	6-7 pt.	107	214
1/16	8-10 pt.	80	160
3/32	11-12 pt.	53	106
1/8	14-18 pt.	40	80
3/32	20-22 pt.	32	64

Table A-II gives a similar presentation for microfilm documents where the FAX scanner is designed to scan the micro image directly in the film plane. The number across the top of the figure represents the amount of photo reduction inherent in the microfilm image.

TABLE A-II. MINIMUM NUMBER OF SCAN LINES REQUIRED TO MEET OBJECTIVES 1 AND 2 FOR MICROFILM MATERIAL

Minimum Character Height (inch)	Minimum Scan Lines Per Inch (LPI) at Film Plane							
	1. Identify Words				2. Identify Individual Characters			
	16×	20×	24×	30×	16×	20×	24×	30×
3/64	1712	2140	2568	3210	3424	4280	5136	6420
1/16	1280	1600	1920	2400	2560	3200	3840	4800
3/32	848	1060	1272	1590	1696	2120	2544	3180
1/8	640	800	960	1200	1280	1600	1920	2400
3/32	512	640	768	960	1024	1280	1536	1920

In tests conducted by the University of Nevada Library under grant from the Council on Library Resources, it was determined that a 96/180 LPI FAX system operating over the dial network via acoustic coupler produced adequate copy for most library material.

2. PICTORIAL CRITERIA

The specification of pictorial criteria is not as straightforward as for text material, due to the tremendously wide range of material types considered and the fact that graphics material is generally not as modular in character as text material. Resolution criteria for a cross section of graphic material is given in Table A-III for applications up to, but not including, reconnaissance photographs where resolutions greater than 2000 LPI and gray scale capability on the order of 64 to 128 levels may be required. Whether facsimile transmission is realistic at these high resolution rates depends on the time sensitivity of the material compared to the channel capacities required.

High scan rates are employed for the transmission of high quality photographic material primarily to minimize noise or interference patterns caused by the interaction of scan lines with the dot arrays constituting the halftone pictures. Costigan [3] indicates that to completely avoid the resulting moire' patterns in FAX reproduction of halftones, the scan resolution must be at least 10 times the halftone screen density in dots per inch, although a seven to one ratio will afford "acceptable" reproduction. Costigan also notes that experience with a multilevel digital (PCM) system has shown that a minimum of from 14 to 20 gray levels is required for reasonably "smooth" reproduction of tonal graduations.

TABLE A-III. TYPICAL RESOLUTION REQUIREMENTS FOR VARIOUS TYPES OF HARDCOPY

Copy Type	Minimum LPI
Line Drawings (no detail)	48
Standard Drafting Letters	80
Handwriting	80
Text of this Report	100
Press Photos	100
Fingerprints	200
Typical Roadway Maps	200
Half-Tone	450-1000
Newspaper Proofs	1000

APPENDIX B

CURRENT STANDARDS DOCUMENTATION AND ISSUES APPLICABLE TO FACSIMILE APPLICATIONS WITHIN THE DCS

1. DEPARTMENT OF DEFENSE DOCUMENTATION

a. MIL-STD-188-120, Military Communication System Standards Terms and Definitions; contains definitions of facsimile terms relevant to analog transmission.

b. MIL-STD-188-100, Common Long Haul and Tactical Communication System Technical Standards.

Par. 4.2.3 Analog Parameters for Facsimile Service - Specifies system levels and parameters for transmission of analog facsimile signals.

Par. 5.7.3.1 Meteorological Facsimile Equipment - Specifies parameters for analog meteorological facsimile transmitters and both small and large format receivers.

Par. 5.7.3.2 General Purpose (Black/White) Facsimile Equipment - This paragraph is reserved for future facsimile consideration.

c. MIL-STD-188-260, Proposed Standards for Tactical Communications Equipment Technical Design Standards for Analog End Instruments and Digital Terminal Equipments.

Par. 5.2.2.8.3 Digital Facsimile - This paragraph is reserved for future facsimile consideration.

Par. 5.3.2.8.1 General Purpose (ANALOG) - Provides signal characteristics and performance standards.

Par. 5.3.2.8.2 Meteorological - Provides signal characteristics and performance standards for both large and small page formats. Similiar to parameters found in MIL-STD-100.

d. MIL-F-55006(1), Specification for AN/TXC-1 Analog Facsimile Set (a 30 and 60 scans per minute machine).

e. AN/6XC-7, Performance Specification for a Militarized Version of MAGNAFAX 850.A - Six Minute Analog Facsimile.

f. AN/UXH-2, Specification for a Military Meteorological Facsimile Machine Complying with World Meteorological Organization Standards.

g. AN/VXC-4, Performance Specification for Lightweight Tactical Digital Facsimile - Completely defines the performance specification for a family of tactical digital facsimile devices. Specifies paper size, resolution, data rates and performance specifications.

2. CIVIL DOCUMENTS

a. EIA RS 328, Message Facsimile Equipment for Operation on Switched Voice Facilities Using Data Communication Terminal Equipment - standard for general purpose analog machines.

b. EIA RS 357, Interface Between Facsimile Equipment and Voice Frequency Data Communication Terminal Equipment - for Analog Facsimile.

c. EIA RS 373, Unattended Operation of Facsimile Equipment (as defined in RS-328).

d. ANSI STD C16.30 (1972), Definition of Terms for Analog Facsimile.

e. ANSI STD C16.45, Facsimile Transmission of Microfilm Documents.

f. IEEE STD 167, Test Procedures for Facsimile.

g. IEEE STD 167A, Facsimile Test Chart.

h. IEEE STD 168, Standard Definition of Facsimile Terms.

3. INTERNATIONAL DOCUMENTS

(1) CCITT, VIth Plenary Assembly, Study Group XIV Final Report - Defines four categories of facsimile devices. Contains proposed standards for resolution, line length, compression code and transmission rate, and proposes a signaling protocol for digital facsimile machines.

(2) ATCA D(76)10, (Allied Tactical Communications Agency), Operational Requirements and Principal Characteristics of Digital Facsimile in the Tactical Environment - Specific requirements for facsimile machines. Proposes specific parameters for paper size, resolutions and transmission rate.

4. MAJOR STANDARDS GROUPS

a. CCITT. Study Group XIV of the International Telegraph and Telephone Consultative Committee represents international efforts to achieve standardization for facsimile. The final report for the VIth Plenary Assembly, dated May 1976, represents the latest official agreements of that body. It has proposed specific parameters for resolution, line length, and the general categories for the signaling protocol and data

compression scheme. The Annual Special Rapporteur's meetings serve to make interim proposals between the four-year periods for the plenary assemblies.

b. BFICC. The British Facsimile Industries Compatibility Committtee represents the next most visible facsimile standards organization. It is comparable to the EIA in the U.S. and coordinates its efforts with those of the EIA. It supports the High Level Data Link Control (HDLC) format for a facsimile signaling protocol. It also supports the other parameters agreed to by the CCITT.

c. EIA TR-29 COMMITTEE. The TR-29 Facsimile Systems and Equipment Engineering Committee of the Electronic Industries Association is the civil standards body within the U.S. considering facsimile. It has proposed the one-dimensional modified Huffman data compresssion scheme tentatively adopted by the Special Rapporteurs of the CCITT. It has also made recommendations to the BFICC to simplify the HDLC type of signaling protocol that has been proposed to the CCITT. It supports the other CCITT agreements to date.

d. FTSC. The Federal Telecommunications Standards Committee (FTSC) Subcommittee on Digital Facsimile was formed in December 1976 to coordinate a Federal Standard. It has made no significant progress as yet. It is chaired by the NCS.

e. DoD. Department of Defense facsimile standardization activities are currently centered around a draft standard proposed by DCA and circulated through DoD via the Joint Steering Committee. This standard was developed by taking the performance requirements from the TRI-TAC specification for a lightweight tactical digital facsimile and selecting specific parameters and characteristics to be compatible with the parameters and guidelines of the CCITT.

5. CURRENT STANDARDS ISSUES

The parameters necessary to achieve full compatibility between facsimile terminals were identified in Section IV - Technical Issues. The current issues involved in the selection of values for each of these parameters are discussed below:

- Picture elements (pels) per line, Horizontal - There appears to be universal support for a standard of 1723 pels/line. The line scan length problem is generally being resolved by scanning a full 8.46 (216 mm) line which will provide coverage for the ISO standard of 210 mm, with some tolerance, and the U.S. standard of 8.5 inches with only the loss of one millimeter.

- Pels per inch vertical. There appears to be general support for

a nominal 100 pels per inch with 200 pels as an option. Specifically, the EIA, CCITT, and NATO propose 97.8 pels/inch with 196.6 pels/inch optional. TRI-TAC has agreed to use these values.

- Aspect Ratio - The EIA, CCITT, and NATO proposals use a nominal 200 x 100 pels/inch with 200 x 200 pels/inch optional. TRI-TAC uses either 100 x 100, 200 x 100, or 200 x 200 pels/inch.

- Gray Scale - All organizations recognize the need for 16 or 32 shades of gray, but parameters for standardization are only being considered for the black and white case at this time. TRI-TAC is developing the capability for up to 16 shades of gray.

- Signaling Protocol - The CCITT has proposed a High level Data Link Control (HDLC) type of format for all terminal-to-terminal facsimile signaling. The EIA has proposed a simplified version. The error sensitivity of the CCITT proposal has not been tested, but is expected to have difficulty above a 10^{-2} Bit Error Rate (BER). TRI-TAC requires survival of start of message (SOM) and end of message (EOM) indicators in a 10^{-3} BER environment.

- Line Sync - The EIA and CCITT have agreed on a sync code word that will survive in a 10^{-3} BER environment with 98.9% assurance. TRI-TAC requires 99.9% in a 10^{-3} BER environment.

- Data Compression Scheme - The EIA and CCITT have selected a variable word length, run length, modified Huffman code in one dimension as a tentative standard for comparison purposes. TRI-TAC uses a two-dimensional code which is not compatible.

- Error Protection - This parameter defines any operation performed on the signaling, facsimile data, compression code or synchronization bits, for the purpose of error detection or correction. The CCITT uses the HOLC protection scheme for signaling protection, while TRI-TAC uses a correlation technique. Both schemes allow errors in the facsimile data.

- Minimum Receiver Scan Time - This defines the maximum rate at which data may be sent to the receiver. The CCITT and EIA propose 10 msec with 6 and 20 msec as options. TRI-TAC uses 13.3 ms.

- Maximum Channel Bit Rate - The CCITT, EIA and NATO have proposed 2.4 and 4.8 kb/s channel rates for use over voice networks. TRI-TAC provides for 2.4 to 16 kb/s to be compatible with future transmission systems.

APPENDIX C

TRENDS IN FACSIMILE TECHNOLOGY

1. LOW COST TRANSCEIVERS

Equipment in this category is designed for the lowest possible terminal lease or sale price. Leases currently range from $29 to $66 per month. Machine operating convenience, hard copy image quality, and paper economy are sacrificed to achieve this cost position. The dial network will continue to be the primary communications medium for this class of terminal, with access gained by means of audio couplers. Within the next few years, the provision of built-in and approved data access arrangements will provide a cost savings alternative to the audio coupler for some applications.

To provide U.S. compatibility, these units use frequency shift keying (FSK) for 4 and 6 minute transmission at resolutions of 64 and 96 lines per inch respectively. Somewhat more expensive models will provide for communications at 2 and 3 minutes per page using the CCITT Group 2 standards at the same resolutions.

To achieve the low equipment cost, a rotating drum and screw mechanism is used for scanning. This means that loading a page of copy into the machine for either transmission or reception will continue to be a relatively awkward task. No relief is in sight in the way of an automatic loading or unloading mechanism except on the more expensive models. However, with the low average utilization typical of the applications using low cost equipment, manual loading is considered to be acceptable. An extra cost option may be added to the higher speed machines to provide for compatibility with all units that operate at 2, 3, 4 and 6 minutes per page.

For minimum cost equipment, a three-step recording process (imagery, developing and fixing) must take place in one operation. There are four recording processes that meet this requirement: electrolytic (wet paper), thermographic (thermally sensitive paper), and high-voltage and low-voltage burn-off (electrosensitive paper). Each of these has its limitations. The quality of electrolytic recording has proven unacceptable for office use. Currently, most low-cost transceivers use high-voltage burn-off paper. However, major objections to the continued use of this type of paper are the considerable odor and poor image quality. Since thermal paper and low voltage burn-off papers eliminate the odor problem, there will be a gradual conversion, over the next 5 years, from high-voltage burn-off to those recording techniques. This will allow some reduction in the price of the supply paper with little impact on the manufacturing cost of the terminal equipment. The resulting elimination of odor should encourage user acceptance, especially in the small office environment which is one of the major markets for this class of terminal.

The minimum cost equipments all use a single stylus in the recording process. Electrothermal paper is heated by a current that passes through the stylus and into the paper. For burn-off papers, the stylus marks the paper by means of a small spark that jumps from the tip of the stylus into the surface of the paper. All single stylus machines use either a drum-with-feed-screw design or a bug-on-a-belt design, with the former providing a less costly and more compact machine. For this reason, most transceivers are drum and screw mechanisms, with a stylus and optical detector located, alternately, in the same head so that both are propelled by the same means.

The electronics, besides providing low level logic functions for control purposes, must provide a number of capabilities not easily implemented with microprocessor (LSI) techniques. These include linear amplification, high-powered drive for the motors, stylus voltage or current, modulation and demodulation filtering, and crystal oscillator timing. Low cost transceivers now on the market utilize discrete components in conjunction with multiple function logic modules. None use LSI technology.

The prospects for significant cost reductions over present low-cost transceivers are excellent. Manufacturing costs are currently between $200 and $500, depending on the manufacturer, but no manufacturer has tooled heavily for the mechanical part. Increasing annual volume for this class machine may soon warrant that kind of investment with the result being a cost reduction of about 30 percent.

It is more difficult to predict any substantial cost reductions in the electronics because of the functional mix of analog, digital, high-power, and high-voltage requirements. The most promising approach incorporates a microprocessor to handle the control functions as well as the analog signaling functions, including modulation and demodulation. Presently available microprocessors should be sufficient. Table C-I lists the numerous functions that can be handled by currently available microprocessors and converter modules. Applications in this area are considered to still be a few years away and will serve more to enhance the operational capabilities of the "low cost" terminal than to provide for any significant cost reduction.

TABLE C-I. FUTURE MICROPROCESSOR APPLICATIONS IN FACSIMILE

a. SENSOR RESPONSE

1. Real Time Clock
2. Interlocks
3. Print Confirmation
4. Low Paper
5. Receiver Loss of Carrier
6. Scanner Start/Stop Markers
7. Abort (Transmission) Request
8. Drum Synchronization
9. Document Address Mark

b. SEQUENCE CONTROL

1. Call Protocol
2. Response Protocol
3. Handshake Mode Signals
4. Between Pages Protocol
5. Scanner Phasing
6. Shut Down
7. Paper Advance Motor

c. SIGNAL PROCESSING

1. Modular Drive
2. Duobinary Inversion
3. Compression Logic
4. Compatibility Changes
5. Station Identification Code Store

2. MEDIUM VOLUME ANALOG TRANSCEIVERS

Medium volume, mailroom transceivers average 10 to 30 transmissions per day and on a busy day may operate almost continuously. Their usage level warrants numerous automatic features such as document feed, unattended reception, and cutting and stacking of received messages. Such automatic features avoid the need for full-time operator attention and permit after-hours transmission and reception. Usually used in a network configuration, mailroom transceivers may also communicate with many low-cost type equipments. Such applications require compatibility with many different type models and makes the technical requirements for mailroom transceivers considerably complex.

The central location in which mailroom transceivers are often placed invites a requirement for a higher quality of printing than the burn-off process can offer. Traffic volumes of 15 to 30 pages per day is high enough to discourage continued use of burn-off (carbon) papers because of the high paper cost and unavoidable vapor products. There is, however, no confirmed demand for the additional costs of plain paper quality. Therefore, one can expect burn-off technology to be replaced with a mix of thermal, dielectric coated paper (DCP) and plain paper techniques. If archival requirements are not dominant, or if they can be met by occasional use of an office-copier, then thermal printing is exceedingly attractive for future applications. Thermal paper is relatively low-cost and the printer requires, as with burn-off, only one step for imaging, developing, and fixing. Such a transceiver can be offered in the price range of $125 to $175 per month including maintenance. Plain paper technology will continue to be exceptionally expensive and DCP printers will fall between thermal and plain papers in complexity and cost.

Transceivers using laser systems for printing will gain economic advantage by using their laser system for document scanning as well. Where thermal or DCP printing is selected, there are two choices for the document scanner system, assuming flat-bed document handling. The less expensive technique mounts light sources and detectors on a belt. The assembly linearly scans the document with a less than 1/2 inch focal length. Alternatively, a solid-state scanner may be chosen using a 1728 cell detector array, in which case the scanner line is imaged upon the array. These systems will give equal performance except that laser systems cannot "see" red colored images on the document. The detector-on-belt scanner will be less expensive and require less tooling than solid-state systems throughout the reminder of the decade, but it incurs a considerable penalty in reliability because of the fast mechanical drive required. Low production volumes in this transceiver category will favor the belt scanner except where the solid-state scanner design can be shared with other transceiver models.

The electronic circuitry of the medium-volume analog transceiver tends to be more complex than that of any other facsimile unit. Its basic design must provide for the many automatic features mentioned above and, in some

models, operation is offered in a full duplex mode, substantially increasing complexity. The demand for compatibility with low-cost units of various manufacture, built to old or new standards, further adds to complexity. Single processing will require both uncompressed and CCITT duobinary video capability. Conventional MSI logic is an expensive means for providing these functional capabilities. MSI is not only expensive in chips, mounts, and power, but relatively inflexible when faced with new requirements. However, since international compatibility will be difficult to achieve for many years for political reasons, flexibility in responding to customer demand and to the incidence of new protocols will be expecially crucial during this period. It can be anticipated that these requirements will be met increasingly through the use of microprocessors for control sequencing and signal processing.

3. MEDIUM-VOLUME DIGITAL TRANSCEIVERS

Design components for this class of equipment have become well-standardized even though units have been in the marketplace for only a little more than five years. Of the half dozen or more models that have been introduced, or that are scheduled for near-term introduction, electrostatic array output printing with fixed array optical scanning and run length digital coding are used almost universally. They also incorporate a 4.8 kb/s modem designed for operation over the public switched network. This design approach will remain constant over the next 3-5 years, but there may be considerable price reductions as competition becomes more severe and manufacturing volumes build up. Present manufacturing costs vary from a low of $3,200 to a high of about $6,000 at the modest production rates adequate for present markets.

The fabrication cost of electrostatic array recording using either dry or liquid toners is well-established and much cost improvement cannot be expected. For the transmitter scanner, those manufacturers using spinning wheel scanners will be converting to solid-state arrays by using 3, 4, or 5 short arrays. Over the next 3 years, there will be a reduction to the standard, single, 1,728 element detector array. This will allow a substantial reduction in the complexity and cost of the transmitter scanning assembly. All manufacturers employ some form of image compression (source redundancy reduction). In at least one instance, this has been accomplished with LSI technlogy, even though the total production volume does not yet permit recovery of the investment cost. During the next 5 years, it can be anticipated that these compression schemes will make use of microprocessors almost exclusively in order to avoid the high initial investment of LSI tooling, to permit reprogramming for the purpose of offering compatibility with other compression schemes, and to offer special-purpose compression codes for select applications.

The modem part of the transceiver is very much "up in the air." Most manufacturers want a 4.8 kb/s modem for the public dial network and a 9.6 kb/s modem for private line application. Until recently, these have been

priced in the low thousands of dollars, but they are now becoming available in substantial volume for $650 to $1,000 each. This will permit a reduction from the upper cost figure of $6,000.

In summary, the cost to manufacturer mailroom digital transceivers, in 1978 dollars, will range between $3,500 and $4,600 each. Where digital transmission circuits are available, the modem can be eliminated for cost savings up to $1,000. Modems will continue to be LSI designed because of the elaborate functional requirements that cannot readily be met by current microprocessor operating speeds. The manufacturing cost, therefore, will remain in the vicinity of $3,500 to $4,600 for the foreseeable future. The leasing rate will be approximately $390 per month, or a reduction of $350 a month below that now charged for the DACOM 412F secure FAX Terminal. There is a school of thought which advocates independent transmitters and receivers for this category of equipment. The separation of the two functions allows any one terminal to be manufactured at approximately two-thirds the cost of the complete transceiver. Should a manufacturer introduce a separate transmitter and receiver pair into the market, possibly half of all potential applications would use only one terminal and, therefore, save one-third in cost.

4. HIGH-VOLUME TRANSMITTERS AND RECEIVERS

Although there are several terminals on the market that can operate at speeds above 9.6 kb/s, the Xerox Long-Distance Xerography (LDX) System can probably be taken as the forerunner of the general-purpose wideband systems of the future. The LDX is designed to operate over a broadband facility such as a 56 kb/s data channel or a Telpak C Channel at 250 kb/s. The current price for the scanner and printer equipment combination is approximately $50,000.

Facsimile-based electronic mail systems are expected to be introduced on a limited basis over the next 5 years. However, development for this category of equipment is currently in a great state of flux with little information available on the direction that design and implementation concepts are taking.

APPENDIX D

SPECIAL PURPOSE FAX-IMAGERY CIRCUITS WITHIN THE DCS

This appendix summarizes the results of a study performed by R200 as part of the preliminary effort to identify the special purpose facsimile applications within the current DCS.

Within the current data base, 162 circuits have been identified as having modulation rates in the facsimile range. These circuits are listed in Table D-I. The following explanation is provided for the codes used in this Table.

a. The first column provides the eight character Command Communications Service Designator (CCSD) for each circuit identified. The first position of the CCSD represents the Command or Agency having the requirement.

A - Department of State
B - Department of the Navy
C - Joint Chief of Staff
F - NCS minor operating agencies
J - Department of the Air Force
L - Federal Aviation Administration
M - NASA
P - Other U.S. Department/Agency
U - Department of the Army
X - Department of Commerce.

The second and third positions indicate the special purpose network to which the circuit belongs in accordance with Table D-II.

Position four indicates the type of service:

D - Data other than DCS switched networks.
J - FAX other than DCS switched networks.
R - Alternate voice/record other than DCS switched networks.
S - Video other than DCS switched networks.
U - Telephoto other than DCS switched networks.
V - Voice other than DCS switched networks.

The remaining positions of the CCSD represent an identification number unique to that circuit.

b. The second and third columns identify the geographic end points for the circuit in question.

c. Column four identifies the modulation rate for the particular circuit in accordance with Table D-III.

TABLE D-I. LIST OF CURRENT SPECIAL PURPOSE FAX-IMAGERY CIRCUITS IN THE DCS.

CMD COMM SVC DESIG	FROM USER CKT TERM	TO USER CKT TERM	MODULATION RATE
LAGJ704F	FRNKSINT02	FIELSON 02	GM
FAHJ5RLJ	GERMNTWN24	WASHNGTN11	GN
FAHJ5RHJ	POCATELL16	SCOVILLE16	GN
FAHJ5RXP	SALTL CY49	MERCURY 32	GN
FAHJ5SC3	LASVEGAS32	SNORNPON06	GG
FAHJ590A	WALLAWLL53	PICHLAND53	GN
FAHJ5SWA	SCHNCTDY36	MTVERNON18	GN
MAND60Y2	WALLOPSI51	SUITLAND24	GR
MANDE0Y0	WALLOPSI51	SUITLAND24	GP
MANJ60CW	HOUSTON 48	HOUSTON 48	GM
BCLJ7JAA	SUGARGRV54	NORFOLK 51	GP
XKEJ5X1W	SANDIEGO06	AFLOAT ZY	GP
BMCJS4VQ	KANEOHE 15	PERLHRBR15	GP
MCDJ60CW	HOUSTON 48	HOUSTON 48	GM
JOAJGP99	OFFUTT 31	SCOTT 17	GP
JCGJGQ14	REDWOOCY06	TRAVIS 06	GG
JCGJGQ15	MTN HOMF16	BOISE 16	GJ
JOGJGQ20	REDWOOCY06	BEALE 06	GJ
JOGSGP33	KANSASCY29	OFFUTT 31	GG
BQIJE059	SAN JUANFQ	LSVLTRQSPQ	GP
RQIJAZ98	NORFOLK 51	OCEANA 51	GN
JQIJE116	SAN JUANRQ	PSVLTRQSRQ	GG
UGIJGR01	WASHNGTN11	FTRITCHI24	GM
UGIJSCSK	HONOLULU15	MICELER 15	GP
UOIJSCZ7	HONOLULU15	KWAJALENTQ	GG
JQIJGP09	SALTL CY49	HILL 49	GP
JQIJWEJP	OFFENBCHGE	KAPAUN GF	GP
BQJJE224	NORFOLK 51	BERMUDA 80	GM
UQJJ7MQE	SALTL CY49	DUGWAY 49	GG
UQJJ3040	FAIRBNKS02	FTGREELY02	GP
UQJJ7HWD	LEXINGTN21	LEXINGTN21	GP
UQJJ7HWE	YUMA 04	YUMA 04	GP
JQJDWGER	LINDSEY GE	WIESBADNGE	GJ
JQJD#GER	RAMSTEINGE	VAIHINGNGE	GG
JQJDWH77	FELDBERGGE	INGIRLIKTU	GG
JQJD#H77	FELDBERGGE	INCIRLIKTU	GG
JQJDWXUK	RAMSTEINGE	UPRHYFRDUK	GG
JQJJA788	OFFUTT 31	YOKOTA JA	GP
JQJJA789	OFFUTT 31	YOKOTA JA	GP
JQJJC606	HEATHRCWUK	KAPAUN GE	GP
JCJJE910	SUITLAND24	USREUALTZV	GP
JQJJGP06	OFFUTT 31	ANDREWS 24	GM
JQJJGP65	SUITLAND24	OFFUTT 31	GP
JQJJGQ30	MIAMI 12	MACDILL 12	GM
JQJJGQ31	REDWOOCY06	MATHER 06	GG
JQJJGQ32	KANSASCY29	CHYANNTRGR	GG
JQJJKS1F	FUCHU JA	YOKOTA JA	GP
JQJJK20G	PERLHRBR15	HICKAM 15	GP
JQJJM6K4	UPRHYFRDUK	WDRAYTCNUK	GM
JQJJQADF	OFFUTT 31	LITTLRCK05	GG
JQJJQ607	OFFUTT 31	KEFLAVIKIC	GP
JQJJSC2J	BUCKET KS	TANGO KS	GR
JQJJSC7J	OSAN KS	YOKOTA JA	GR
JQJJ4FN3	YOKOSUKAJA	YOKOTA JA	GP
JQJJSCHF	HONOLULU15	BRADSHAW15	GP
JQJJS499	YOKOTA JA	YOKOTA JA	GJ
JQJJS503	TAEGU KS	KWANGJU KS	GG
JQJJS530	YOKOTA JA	TAEGU KS	GJ
JCJJS501	TAEGU KS	OSAN KS	GG
JQJJS502	BUCKET KS	YONG SANKS	GG
JQJJS533	YOKOTA JA	KADENA JA	GG
JQJJS594	FTBUCKNRJA	TAIPEI TW	GG
JQJJS504	CLARK RP	GRASMTNTW	GG
JQJJS505	FTBUCKNRJA	CLARK RP	GG
JCJJS506	YOKOTA JA	CLARK RP	GG
JQJJS536	CLARK RP	ANDERSENGG	GG
JCJJS507	YOKOTA JA	IWAKUNI JA	GG
JQJJS508	YOKOTA JA	MISAWA JA	GG
JQJJWH05	MAIN GE	VAIHINGNGE	GG
JQJJWXUK	CRDJGHTNUK	DARMSTDTGE	GP
JQJJW157	MTLSHMHTUK	WTHRSFLDUK	GP
JQJJUSAT6	NIMITZHLGG	FINEGAYNGG	GN
JQJVS225	HONOLULU15	HICKAM 15	GP
PSWJSAND	BALTIMOR24	WASHNGTN11	GP
ATEJSABQ	WASHNGTN11	NYORK CY36	GM
UQRJL022	OFAL 34	SUITLAND24	GM
JQGRZHAK	LOWRY 08	WASHNGTN11	GP
BWKJK2P2	ADAK 02	ADAK 02	GP
BWXJSCTW	PERLHRBR15	BARBRSPT15	GP
BWXJSCWJ	HONOLULU15	PERLHRBR15	GP
BWXJS478	YOKOSUKAJA	KAMISGYAJA	GM
BWXJWFXI	SIGONELLIT	CAPODICHNIT	GM
BWXJ7JAA	SUGARGRV54	PATXNTRV24	GP
BWXJ9X51	ROTA SP	SIGONELLIT	GM
BWXJ9X51	ROTA SP	SIGONELLIT	GM
BWXJ9X51	ROTA SP	MORON SP	GM
BWXJ9X51	ROTA SP	MORON SP	GM

TABLE D-I (CONT'D)

CMD COMM SVC DESIG	FROM USER CKT TERM	TO USER CKT TERM	MODULATION RATE
XXFJ5XKN	SUITLAND24	LA JELLA06	GD
XXFJ5XKT	SUITLAND24	PORTLAND23	GD
XXFJ5XKS	SUITLAND24	NORLEANS22	GD
XXGJ5XPU	SUITLAND24	SAN JUAN60	GD
XXGJ5XHP	SUITLAND24	BRENTWOD36	GD
XXJJ7325	FTGREELY02	FTGRELLY02	GD
XXJJ7996	ANCHOMA002	FSTEMDCM02	GD
XXMJ5XE0	SUITLAND24	PT MUGU 06	GD
XXMJ5XE1	OAKLAND 06	NORFOLK 51	GD
XXNJ5XA0	SUITLAND24	GARDENCY20	GD
XXNJ5XA1	GOODLAND20	KLMTHFLS41	GD
XXNJ5XA2	KLMTHFLS41	WARRENTN41	GD
XXNJ5XD0	SUITLAND24	CHARLSTN45	GD
XXNJ5XD1	GREENSBR37	GRLENSBR37	GD
XXPJ5XGS	ALBUQUR035	PHOENIX 04	GD
XXPJ5XGT	AUBURN 53	SALTL CY49	GD
XXPJ5XGU	AUBURN 53	RENO 32	GD
XXPJ5XHD	AUBURN 53	MCCHORD 53	GD
XXPJ5XHE	LOSANGLS06	PALMDALE06	GD
XXQU5XLM	FAIRBNKS02	JUNEAU 02	GD
XXQU5XDA	BISMARCK38	KANSASCY29	GD
XXQU5XDB	PORTLAND41	REDWODCY06	GD
XXQU5XDC	SEATTLE 53	REDWODCY06	GD
XXQU5XDD	CP SPR 24	DETROIT 26	GD
XXQU5XDE	BOSTON 25	CP SPR 24	GD
XXQU5XDF	NYORK CY36	CP SPR 24	GD
XXQU5XDG	MEMPHIS 47	KANSASCY29	GD
XXQU5XDH	KANSASCY29	NORLEANS22	GD
XXQU5XDI	REDWODCY06	SALTL CY49	GD
XXQU5XDJ	CP SPR 24	ATLANTA 13	GD
XXQU5XDK	CHICAGO 17	KANSASCY29	GD
XXQU5XDL	DENVER 09	KANSASCY29	GD
XXQU5XGM	DIPMNGHM01	KANSASCY29	GD
XXQU5XDN	CP SPR 24	CHARLSTN54	GD
XXQU5XDP	PORTLAND23	CP SPR 24	GD
XXQU5XDQ	KANSASCY29	MINNEPLS27	GD
XXQU5XDR	KANSASCY29	ALBUQUER035	GD
XXQU5XDS	CP SPR 24	COLUMBIA45	GD
XXQU5XDT	ALBANY 36	CP SPR 24	GD
XXQU5XDU	BUFFALO 36	CP SPR 24	GD
XXQU5XDV	CP SPR 24	CLEVELND29	GD
XXQU5XDW	REDWODCY06	PHOENIX 04	GD
XXQU5XDX	CHEYENNE56	KANSASCY29	GD
XXQU5XDY	KANSASCY29	MILWAUKE55	GD
XXQU5XLQ	CP SPR 24	SAN JUAN60	GD
XXQU5XHF	KANSASCY29	ST LOUIS29	GD
XXQU5XNG	KANSASCY29	SANANTON49	GD
XXQU5XNH	KANSASCY29	FT WORTH48	GD
XXQU5XNI	KANSASCY29	OKLAHCY40	GD
XXQU5XNJ	KANSASCY29	LUBBOCK 49	GD
XXQU5XNK	KANSASCY29	TOPEKA 20	GD
XXQU5XNL	KANSASCY29	LITTLERCK05	GD
XXQU5XNM	REDWODCY06	LOSANGLS06	GD
XXQU5XNN	REDWODCY06	RENO 32	GD
XXQU5XNP	GT FALLS20	REDWODCY06	GD
XXQU5XNQ	BOISE 16	REDWODCY06	GD
XXQU5XNR	CP SPR 24	RALEIGH 17	GD
XXQU5XNS	CP SPR 24	PHILDLPHA2	GD
XXQU5XNT	CP SPR 24	PITTSBRGH42	GD
XXGU5XNU	INDINPLS18	KANSASCY29	GD
XXQU5XNV	JACKSON 28	KANSASCY29	GD
XXQU5XNW	KANSASCY29	OMAHA 31	GD
XXQU5XNX	DESMOINS19	KANSASCY29	GD
XXQU5XNY	LOUISVLL21	KANSASCY29	GD
XXQU5XNZ	KANSASCY29	SIOUXFLLS46	GD
XXZJ5XKA	CEDRGBLS12	COCOA 12	GD
XXZJ5XLJ	REDWODCY06	SALTL CY49	GD
XXZJ5XLK	SILVRSPR24	KANSASCY29	GD
XXZJ5XLL	KANSASCY29	SALTL CY49	GD
XXZJ5XLP	SUITLAND24	KEY W 12	GD
XXZJ5XLS	REDWODCY06	LA JOLLA06	GD
XXZU5XKU	SUITLAND24	HONOLULU15	GD
XXZU3XLN	PT REYES06	REDWODCY06	GD
J7MV#DRT	ALCNDAYUK	WATTON UK	GM
J7RJUF98	PITTSBRG GE	SPNGDALMGE	GM

DCS PURPOSE/USE CODES

TABLE D-II.

AG - Federal Aviation Administration

AH - Atomic Energy Commission

AN - NASA Communications Network

CL - Control Line

KE - NMFS Southwest Telecommunciations Systems

MC - U.S. Marine Corps

OD - Operational Tracking and Data Acquisition

QA - MAC Command Control Record Communications System

QG - Weather Teletypewriter

QI - Weather FAX (Civil, U.S. Weather Bureau)

QJ - Weather FAX

SW - Designators not identified in current version of DCA Cir 310-65-1

TF - Department of State

UB - Common User Voice Service

UE - Common User Digital Data (excluding teletype)

WX - Navy Weather

XF - Automation of Field Operations and Services

XG - NWS International Weather Communications System

XJ - NWS Intra-Alaska FAX Network

XM - NWS National and Aviation Meterological FAX System

XN - NWS RRS Radar Remote System

DCS PURPOSE/USE CODES

TABLE D-II (cont.)

XP - NWS National Facsimile Network

XQ - GOES, Telephoto Facsimile System

XZ - NWS Miscellaneous Weather Communications System

ZM - Military Air Traffic Control and Flight Facilities Network

ZR - Flight Following/Air OPS Service Network

TABLE D-III. CIRCUIT MODULATION RATES

GM - 60 scan FAX

GN - 75 scan FAX

GP - 120 scan FAX

GQ - 240 scan FAX

GR - 400 scan FAX

APPENDIX E

CALCULATIONS

1. OPERATING COSTS FOR THE DIFFERENT CLASSES OF FACSIMILE EQUIPMENT (SECTION II).

Table E-1 gives the range in costs for low, medium and high speed facsimile equipment and provides the basis for evaluating facsimile equipment operating costs as summarized in Section II of this report.

TABLE E-I. THE RANGE IN OPERATIONAL COSTS FOR THE MAJOR CLASSES OF CURRENT FACSIMILE EQUIPMENT

COST CATEGORY	CLASS OF FACSIMILE EQUIPMENT		
	CATEGORY I	CATEGORY II	CATEGORY III
HARDWARE RENTAL ($/MO)	$28-$110	$65-$200	$300-$625
PAPER ($/PAGE)	$.08-$.12	$.03-$.12	$.03-$.06
TRANSMISSION ($/PAGE)	$.60-$1.05	$.30-$.60	$.08-$.23
OPERATOR ($/PAGE)	$.32-$1.12	$.16-$.70	$.04-$.42

The three speed ranges are for 4 to 6 minutes (Group I), 2 to 3 minutes (Group II), and sub-one minute (Group III). The change in paper costs with increasing speed reflects the need of special, more expensive paper for use in the less expensive equipment. Transmission costs are based on an equivalent value of 45 cents for an average three minute AUTOVON call. Although AUTODIN may be the primary means for satisfying Group III requirements, a typical transmission cost figure for AUTODIN was not included since AUTODIN can absorb additional traffic at this time. Transmission time also includes the time required to initiate the call.

Operator costs are based on the fact that Group I operation requires the operator to load the machine manually and then unload the machine four to six minutes later. Group II equipment can have either a manual loading system or an automatic feeder. Group III equipment typically has automatic feed. Accordingly, typical operator times for the three classes of

equipment are between four and eight minutes for Group I, two to five minutes for Group II, and 30 seconds to three minutes for Group III. Assuming a wage rate equivalent to a GS-4/4 at the low end and a mix of GS-4/4 and GS-13/4 in a ratio of 3:1 at the high end, operator costs become as shown in the Table.

2. PROJECTED GROWTH OF FACSIMILE DEMAND IN DoD (SECTION III)

Table E-II gives the range in expected DoD terminal growth for each of the major classes of facsimile equipment. This table is based on the Yankee Group "Most Likely" estimate of total facsimile terminal growth, given in Table IV (Section II), modified to reflect a five to twelve percent range as DoD's share of that growth. The low and high estimates are distributed according to equipment class in proportion to IRD's estimate of terminal distribution as given in Table V (Section II).

TABLE E-II. DoD TERMINAL GROWTH ESTIMATE

YEAR	LOW ESTIMATES				HIGH ESTIMATES			
	GROUP I	GROUP II	GROUP III	TOTAL	GROUP I	GROUP II	GROUP III	TOTAL
1978	7084	725	241	8050	17,002	1739	579	19320
1980	7950	2226	424	10,600	19,080	5342	1018	25440
1982	7587	5761	702	14,050	18,209	13825	1686	33720
1989	6562	11580	1158	19,300	15,749	27792	2779	46320

The estimated facsimile traffic volume for a given year can now be derived by applying the appropriate information contained in Tables E-II through E-V in the following general formula:

Total Traffic (bits per day) = Total number of terminals in each equipment class [E-II], times the average daily volume for a typical terminal in each class [E-III], times the average resolution typical of each class [E-IV], times the average copy size (8"x10-1/2"), times a typical compression ratio for each equipment class [E-V].

3. TYPICAL FACSIMILE NETWORK COSTS (SECTION V)

a. Desk Top Convenience Fax. A comparison of the costs of various network solutions for desk top FAX were given in Section V (Figures 15 and 16). These comparisons assume:

TABLE E-III. CURRENT AND PROJECTED FACSIMILE TERMINAL AVERAGE VOLUMES IN PAGES PER MONTH

	NEAR TERM (1979-1983)	MID TERM (1984-1989)	FAR TERM (1990-1994)
LOW SPEED (Category I)	15		10
MEDIUM SPEED (Category II)	150		50
HIGH SPEED (Category III)	700		500
WIDEBAND	-		2000

TABLE E-IV. CURRENT AND PROJECTED INCREASE IN RESOLUTION REQUIREMENTS FOR DoD USERS (LPI)

	NEAR TERM (1979-1983)	MID TERM (1984-1989)	FAR TERM (1990-1994)
LOW SPEED (Category I)	64	100	100
MEDIUM SPEED (Category II)	100	100	200
HIGH SPEED (Category III)	100	200	200
WIDEBAND	200	400	1000

TABLE E-V. CURRENT AND PROJECTED INCREASE IN DATA COMPRESSION RATIOS FOR FACSIMILE TRANSMISSION

	NEAR TERM (1979-1983)	MID TERM (1984-1989)	FAR TERM (1990-1994)
LOW SPEED (Category I)	1:1	(1:30)*	(1:50)*
MEDIUM SPEED (Category II)	1:1	1:10	(1:50)*
HIGH SPEED (Category III)	1:5	1:15	1:20
WIDEBAND	1:20	1:30	1:50

* Compression Provided as a network feature rather than in the terminal.

- An average cost of $1.42 is assumed for a 3-minute, DoD initiated commercial call, as determined from a daily billing sample totaling over $100,000 in charges.

- A cost of $.90 for 6 minutes of use is added to the government's costs to cover the incremental value of AUTOVON service.

- The leased value, rather than the purchased value, for facsimile equipment (nominally $28 to $38 per month for desk top equipment) is used for ease of computation. However, since the same costs are associated with both alternatives, this assumption does not bias the comparison.

b. Centralized Convenience/Mailroom Operation. Cost comparisons between AUTOVON, AUTODIN, and the public dial-up network for both secure and non-secure centralized convenience and mailroom FAX applications are depicted in Section V (Figures 17 through 20). The calculations associated with each of these figures are provided in Tables E-VI through E-IX. The following considerations apply to the development of these tables:

- The backbone charges for AUTODIN are taken from the current DCA Cost Manual [15] for a lower and less expensive data rate than normally encountered to reflect the capability for data compression over AUTODIN.

- The backbone charge for AUTOVON is taken for a subscriber authorized to place only ROUTINE precedence calls within CONUS.

- The switch termination charge for AUTOVON includes the connection to switch, service terminal, and dial signaling charges as prescribed in Figure 27-1 of the current DCA Cost Manual [15]. The costs for AUTODIN reflect charges for the modem, protocol box, and header insertion device. Monthly charges for purchased equipment have been based on an 8-year life cycle.

- Access line charges are based on an average access distance of 100 miles for AUTOVON and 300 miles for AUTODIN. A charge in the commercial column for access line costs reflects the need for installation of a ccommercial data access arrangement at most equipment locations.

- The costs used for the facsimile terminal equipment are taken from the GSA schedule, and include maintenance charges. The costs reflect a typical analog facsimile terminal with automatic loading and transmission/reception features for the AUTOVON and commercial applications, and a DACOM 412G for the AUTODIN application.

TABLE E-VI. NON-SECURE CENTRALIZED CONVENIENCE/MAILROOM OPERATION - INCREMENTAL USER COSTS (MONTHLY)

ITEM	AUTOVON	"PIGGY BACK" AUTOVON	AUTODIN	COMMERCIAL
BACKBONE	$223		$5,328	
Interface Costs	135		245	
Access Line	49		146	$ 25
Fax Terminal	184	$184	674	184
TOTAL	$591	184	$6,393	$209
Transmission Costs (per page)	--	--	--	$2.84

TABLE E-VII. NON-SECURE CENTRALIZED CONVENIENCE/MAILROOM OPERATION INCREMENTAL GOVERNMENT COSTS (MONTHLY)

ITEM	AUTOVON	"PIGGY BACK" AUTOVON	AUTODIN	COMMERCIAL
BACKBONE				
Interface Costs	$135		$ 245	
Access Line	49		146	$ 25
Fax Terminal	184	$184	674	184
TOTAL	$368	$184	$1,065	$209
Transmission Costs (per page)	$.90	$1.01	--	$2.84

TABLE E-VIII. SECURE CENTRALIZED CONVENIENCE/MAILROOM OPERATION - INCREMENTAL USER COSTS (MONTHLY)

ITEM	AUTOVON	"PIGGY BACK" AUTOVON	AUTODIN	COMMERCIAL
BACKBONE	$ 223		$5,328	
Interface Costs	270	$135	245	$135
Access Line	49		146	25
Fax Terminal	674	674	674	184
TOTAL	$1,216	$809	$6,393	$834
Transmission Costs (per page)	--	--	--	$.57

TABLE E-IX. SECURE CENTRALIZED CONVENIENCE/MAILROOM OPERATION - INCREMENTAL GOVERNMENT COSTS (MONTHLY)

ITEM	AUTOVON	"PIGGY BACK" AUTOVON	AUTODIN	COMMERCIAL
BACKBONE				
Interface Costs	$270	$135	$ 245	$135
Access Line	49		146	25
Fax Terminal	674	674	674	674
TOTAL	$993	$809	$1,065	$834
Transmission Costs (per page)	$.18	$.20	--	$.57

- No value is associated with the use of AUTODIN from the viewpoint of the government, since the Pacific AUTODIN is currently considered to be underutilized and can absorb some increase in traffic volume without additional assets, as discussed in subsection V-3 AUTODIN. This may not be the case, however, for the European AUTODIN, which is currently considered to be heavily loaded.

- A separate alternative labeled "VON Piggy Back" has been included for those applications where AUTOVON service is currently available and an additional access line is not required. An additional cost of $.11 per page transmitted is added, however, to reflect the fact that additional access lines will be required to maintain current grade of service as volume grows.

4. AUTOVON IMPACT ANALYSIS

a. AUTOVON Traffic Boundary Values. The expected impact of increasing busy hour facsimile demand on AUTOVON was given in Section V (Figures 21 through 26). Two traffic options are assumed in constructing these figures. These options are considered to be reasonable boundaries to what will most likely occur over the next 3 to 5 years. These boundaries are based on the following assumptions:

- A traffic generating function given by:

$$T_x = X \frac{\sigma\frac{P_1 S_1}{6} + \rho\frac{P_2 S_2}{10}}{60}$$

where

X = number of terminals in the population for each snapshot (5,000, 10,000, 25,000 and 40,000).

T_x = total traffic generated by these terminals in erlangs.

σ, ρ = the percentage of desk top and mailroom FAX terminals respectively.

P_1, P_2 = number of pages per day for desk top (P_1) and mailroom (P_2) applications. (P_1 low = 2, P_1 high = 4, P_2 low = 6, P_2 high =18).

S_1, S_2 = time to transmit one page in minutes (S_1 = 6, S_2 = 2).

- The percentage of desk top terminals (70 percent) with respect to mailroom terminals (22 percent) within DoD is taken to be the same as for the country as a whole, although the growth of desk top terminals may be somewhat less if there is a major effort to provide over-the-counter service at each major DoD installation.

- The values for terminal operating speeds, used in the equation, reflect a bias towards the lower speed in the low option and towards the higher speed in the high option because higher utilization will encourage the use of higher speed transmission capabilities.

- Inter-area facsimile transmission was not addressed because normal duty hour ROUTINE AUTOVON service between CONUS and the overseas areas is not feasible within the constraints of current inter-area trunking assets.

b. After-Hours AUTOVON Analysis. The excess AUTOVON capacity available for facsimile service during the off-hours is depicted in Section V (Figures 28-29 and 32-33). The following approach was taken in developing the after hours analysis.

In order to assess the effect of different holding times for voice calls and facsimile service in a network, such as the AUTOVON, which consists of interswitch trunks equipped with multilevel precedence and preemption capability, a new analytical network model was required. Twenty-four hour traffic estimates, developed by DCA Code 520 from data obtained by the Traffic Data Collection System (TDCS), were used in this study. Using the newly developed model and the TDCS traffic data, the network performance and economic impact of facsimile service upon the AUTOVON was then assessed.

American Telephone and Telegraph (AT&T) Long Lines was requested to provide a twenty-four hour CONUS AUTOVON traffic profile for use in this study. Due to problems with the processing of off-hour traffic data collected from CONUS AUTOVON switches, AT&T was unable to develop the off-hour CONUS AUTOVON traffic profile, although an AT&T traffic engineer familiar with the CONUS AUTOVON network did provide a "best guess" evaluation based on his past experiences with the network. This estimate is used for the CONUS portion of the after-hours analysis.

The current configuration of the European AUTOVON, incorporating the switch at Donnersberg, Germany as a fourth gateway to CONUS, was used in determining the available capacity and network performance for facsimle service. The configuration of the PACIFIC AUTOVON used in this study is scheduled to be implemented in 1981 and utilizes the switch at Fort Buckner, Okinawa as a fourth gateway to CONUS.

The following assumptions were used in this study:

- Voice calls placed after hours can preempt facsimile service transmissions.
- Facsimile transmissions which are preempted are not re-attempted.
- No growth of voice traffic was assumed.
- The nominal holding time of a voice call would be three and-a-half minutes.
- The average holding time of a facsimile transmission would be four times as long as the holding time of a voice call for slow inexpensive terminals, and twice as long for high speed facsimile service terminals.

c. AUTOVON Link Fill Analysis. The AUTOVON simulation model, used to evaluate the impact of AUTOVON constraints on the potential facsimile uses in Section V of the report, also provided considerable insight into the relative utilization of the AUTOVON network. A typical utilization profile for the Pacific network is given in Figures E-I and E-II as an example of the capabilities of this simulation model.

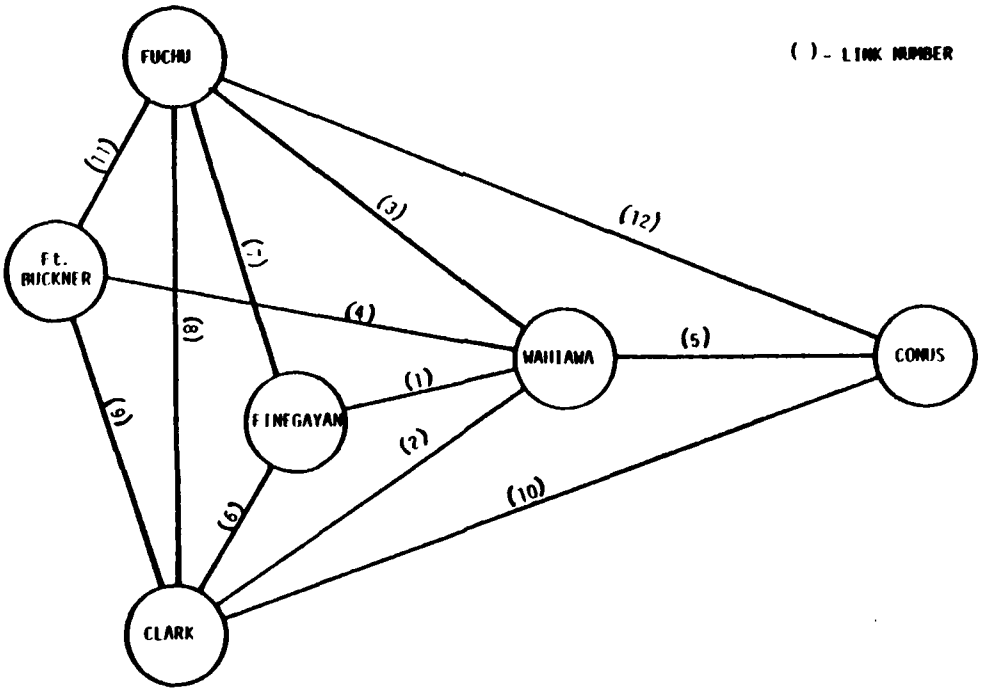

Figure E-1. Pacific AUTOVON Link Configuration

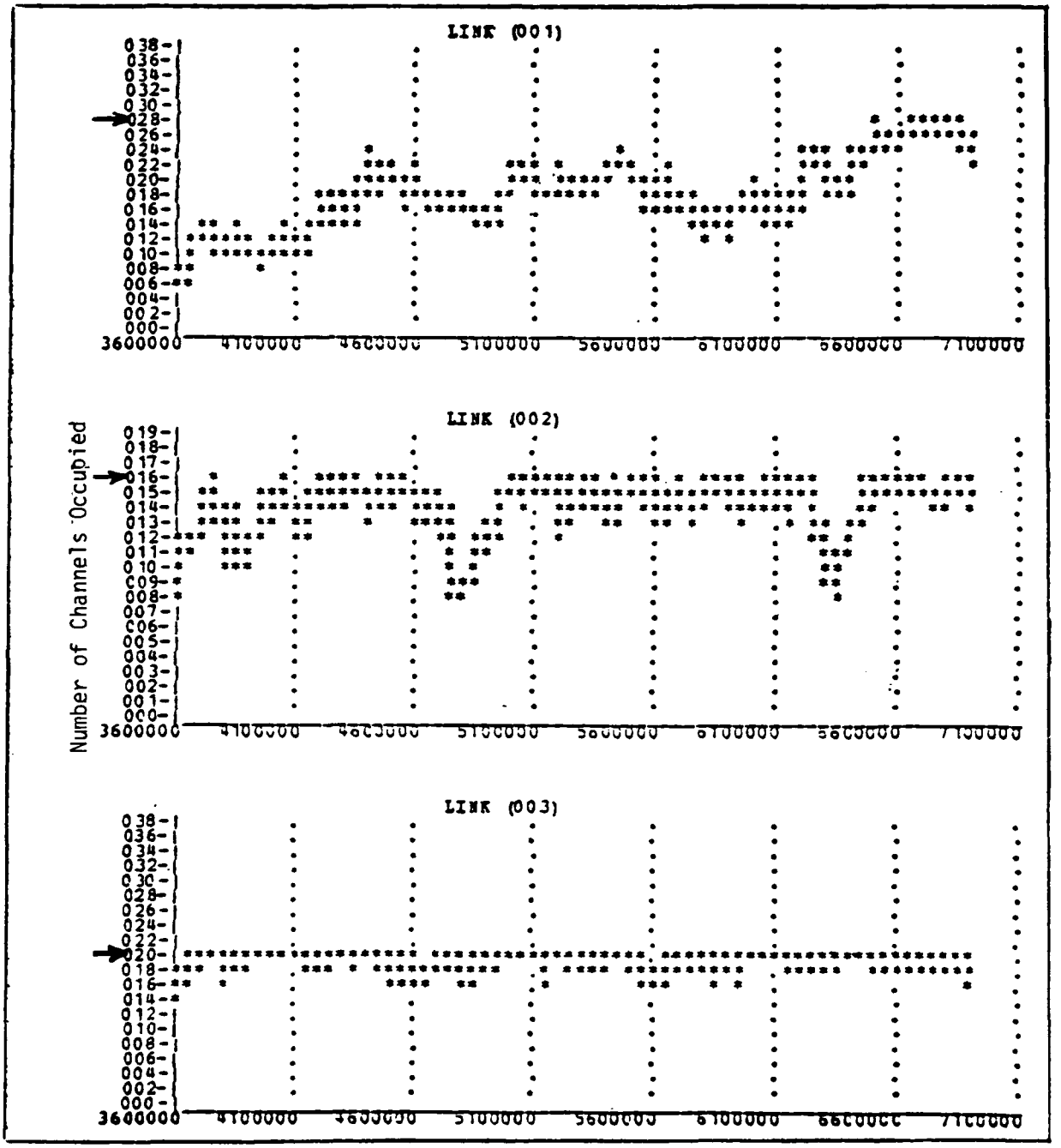

Figure E-2. Pacific AUTOVON Link Fill Simulation

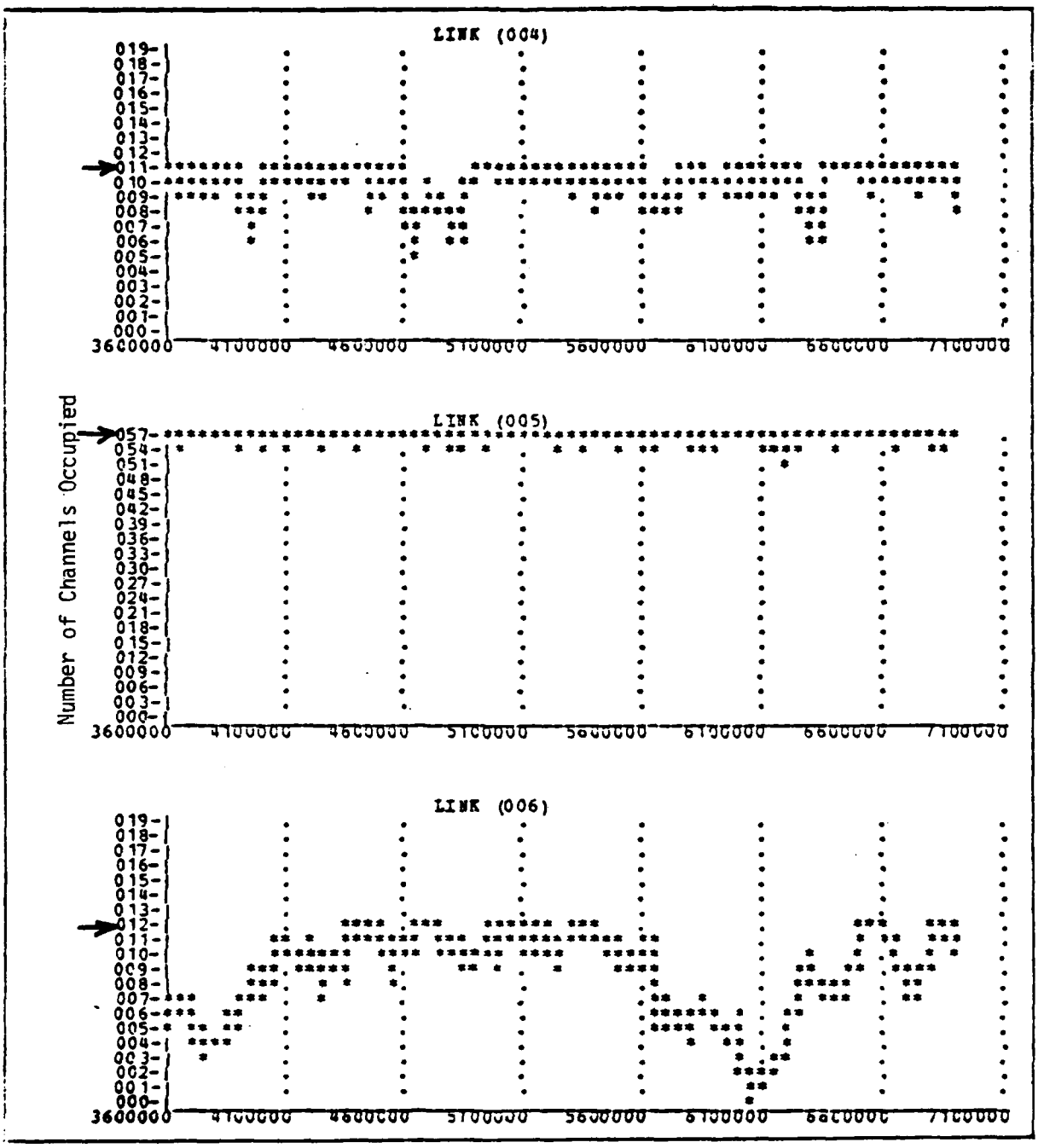

Figure E-2 (Cont'd). Pacific AUTOVON Link Fill Simulation

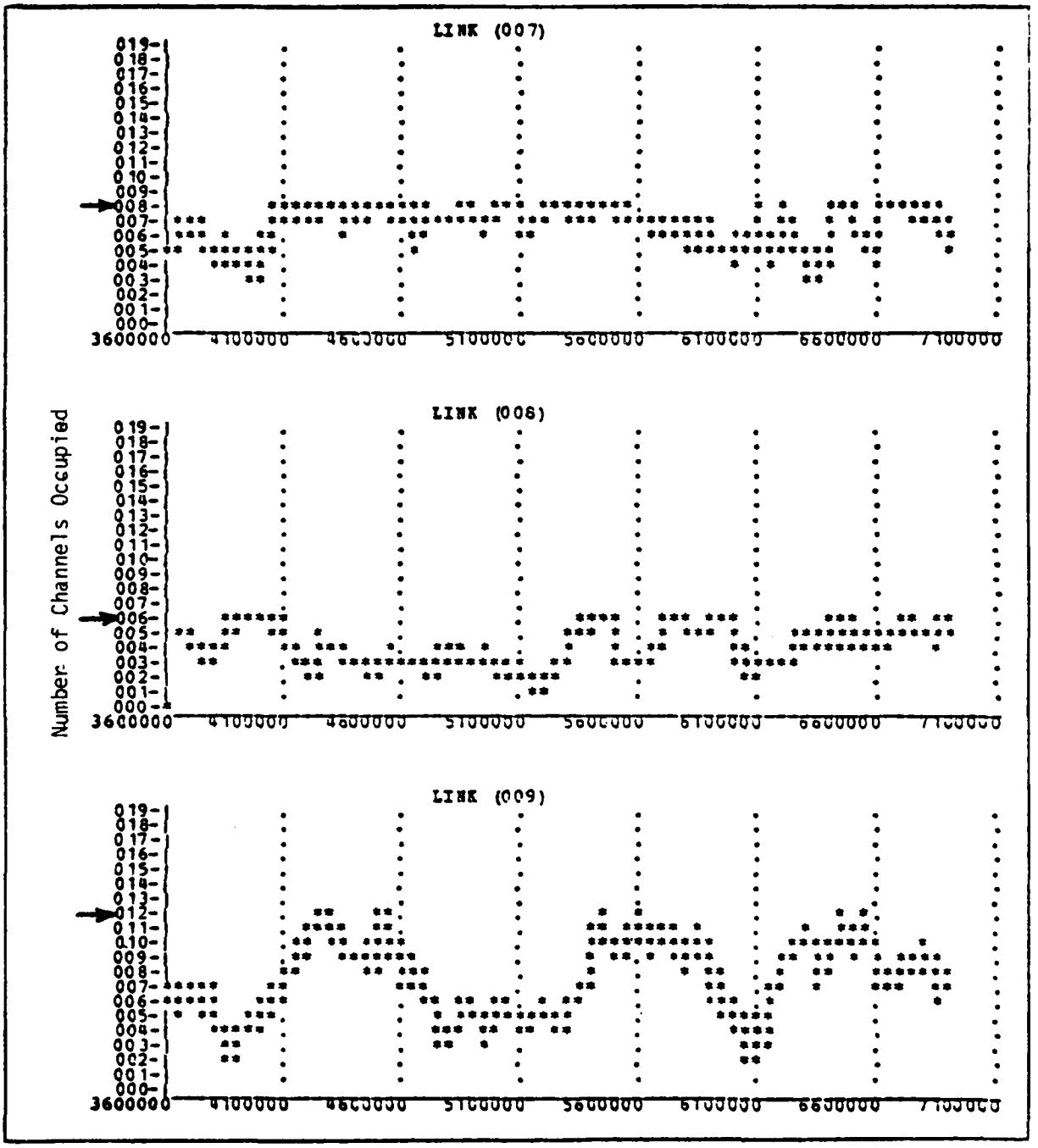

Figure E-2 (Cont'd). Pacific AUTOVON Link Fill Simulation

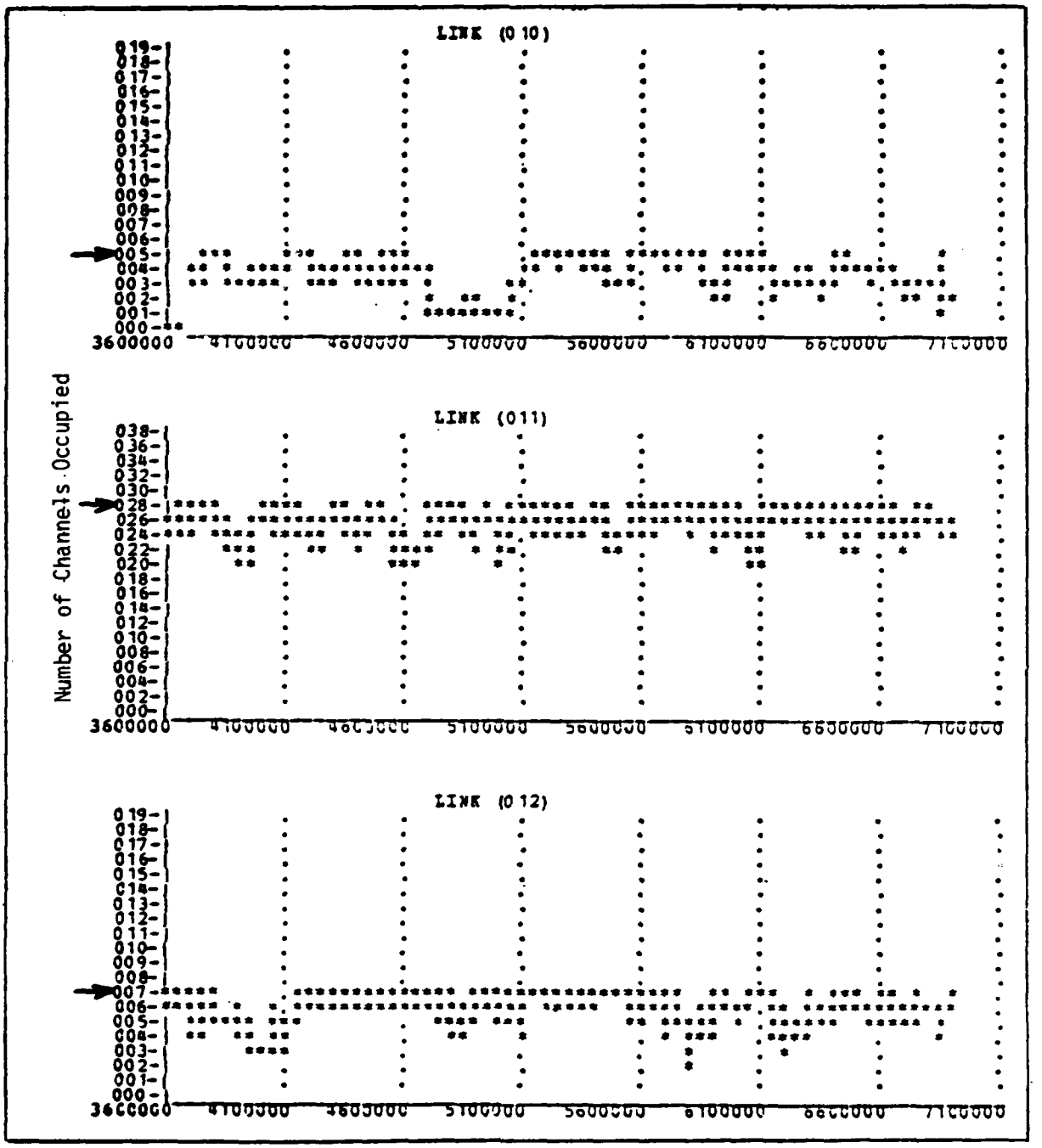

Figure E-2 (Cont'd). Pacific AUTOVON Link Fill Simulation

5. AUTODIN IMPACT ANALYSIS (SECTION V)

The impact of increasing facsimile demand on the Pacific AUTODIN was addressed in Section V (Figures 38 and 39). The following additional factors were considered in developing the figures:

- The conversion from traffic volume to number of terminals is given as:

$$N = \frac{560(3600T)}{.1667P_xR_x}$$

where

N = number of terminals.

T = traffic volume in lb/s.

P_x = pages transmited per day for high or low utilization rates.

R_x = number of bits per page at a given resolution assuming a 5:1 compression ratio (187,000 for 100 LPI and 292,187 for 125 LPI)

560 is the number of information bits in a line block; 3600 is the number of seconds in the busy hour.

- The average numbers of pages (P_x) per day assumed for high and low utilization are 30 and 10 respectively. This figure is converted to a busy hour figure by dividing by 6 (multiplying by .1667).

- The resolution assumed for low utilization is 100 LPI and for high utilization 125 LPI in recognition of a possible trend to higher resolution requirements in the copy mix at higher utilization levels.

- Only mailroom facsimile applications are considered, since it is assumed that the high cost of digital facsimile procludes convenience operation, at least in the near term.

DISTRIBUTION LIST

STANDARD:

R100 - 2
R102/R103/R103R - 1
R102M - 1
R102T - 9 (8 for stock)
R104 - 1
R110 - 1
R123 - 1 (Library)
R124A - 1 (for Archives)

R200 - 1
R300 - 1
R400 - 1
R500 - 1
R700 - 1
R800 - 1
NCS-TS - 1
101A - 1

222 - 13

DCA-EUR - 2 (Defense Communications Agency European Area
ATTN: Technical Director
APO New York 09131)

DCA-PAC - 1 (Defense Communications Agency Pacific Area
ATTN: Technical Director
Wheeler AFB, HI 96854)

USDCFO - 1 (Chief, USDCFO/US NATO
APO New York 09667)

AFSOUTH - 1 (Chief, DCA Field Office, Italy
Box 166, AFSOUTH (NATO)
FPO New York 09524)